DOCUMENT RESUME

ED 175 829 SP 014 576

AUTHOR	Adrian, Marlene, Ed.; Brame, Judith, Ed.
TITLE	NAGWS Research Reports. Vol. III.
INSTITUTION	American Alliance for Health, Physical Education, and Recreation, Washington, D.C. National Association for Girls and Women in Sport.
PUB DATE	77
NOTE	190p.
AVAILABLE FROM	AAHPERD Publications, 1201 16th St. N.W., Washington, D.C. 20036 (Stock #243-26004; $7.75)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Exercise (Physiology); *Human Body; Injuries; Motor Development; Performance Factors; Physical Education; *Psychomotor Skills; Self Concept; Sex Differences; Social Attitudes; Teamwork; *Womens Athletics

ABSTRACT

The emphasis in this collection of research reports is on women athletes, their training, physical characteristics, and mental attitudes. Each article describes a research project on one of these topics, the methodology used to obtain findings, analysis of results, and a summary of applications a teacher or coach may use. (JD)

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NAGWS

RESEARCH REPORTS VOLUME III

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1201 Sixteenth Street, N.W.
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PREFACE

Persons dealing with the organization, administration and teaching of human movement skills, especially in the athletic world, are confronted with a multitude of questions which must be answered if they are to be successful.

What effect will new equipment have upon performance? What is the mechanically ideal way to perform a skill? What types of social interactions adversely influence performance? What are the characteristics of a champion athlete? What can be done to insure adequate training for the performance? How can injuries be prevented and what type of recording of injuries should be undertaken? What are the ways to assess potential ability, as well as present ability?

The need to answer these and other questions was the impetus for publishing this third volume of *Research Reports*. Its special emphasis is upon the female in athletics; it is designed to provide a synthesis of research and practice. Each article includes a final section summarizing certain applications which the teacher or coach can make, or poses questions of concern to the practitioner. Since many of the authors are coaches or athletes, as well as researchers, this publication should be a valuable resource to the practitioner when making decisions or asking others to conduct pertinent research into the world of athletics for the female.

Marlene Adrian
Judith Brame
Editors

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RESEARCH — WHO NEEDS IT?

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What is research, and of what importance is it to the female athlete now and in the future? Research may be either a search for the truth or merely satisfying one's curiosity. It can also be thought of as the scientific way to solve problems.

Today's athletic programs ask girls and women to perform in ways and at levels not previously achieved. So many changes are taking place that we must search again for new answers to questions asked many years ago, the answers to which have changed in light of new programs, new challenges, and the new physique and attributes of the female and the female athlete in particular.

Is the female athlete really handicapped? Only research — action-oriented research — can tell us. Research must come out of the laboratory and become the common property of every interested coach and teacher.

Research has helped create such new playground material for children as space cities and geodesic domes to challenge children's imagination and creativity. It has helped us discover how fundamental motor patterns develop, and it cues us if development is not progressing at the normal rate or if special problems exist.

One does not have to be a high-powered specialist to do research, whether it be in physiology, biomechanics and kinesiology, or socio-psychology. For example, the coach can do much in physiology when she advises an athlete on proper diet and fluid balance during competition and supplies her with research-supported findings concerning vitamins, supplements, and other ergogenic aids. Other physiologic parameters can be used to assess the condition of the athlete or student. The pulse rate can be used as an indication of the physiological condition of the athletes. Pedometers can be used to measure how far athletes really run and, consequently, the level of conditioning needed. Recording injuries is also a type of research, as it provides data for the coach and others. A treadmill, if available, can be used to determine oxygen uptake and heart rate.

The area of anthropometry consists of measuring body lengths, breadths, and girths as well as somatotyping. Anthropometry enables the coach to identify particular body types that might be best for certain activities and identify any inadequacies in body build that an athlete might have to overcome. For example, a very short person must raise the center of gravity in the high jump much higher than a taller person.

Determining segmental centers of gravity will help in calculating rotational inertia. For example, persons with the same muscle mass and dissimilar centers of gravity will have different movement velocities, since their rotational velocities will vary. To put it differently, a person with a heavy hand will not be able to move as fast as a person with a lighter hand.

The next area of research concerns videotaping and cinematography. The videotape is probably the single most important tool that has come into wide use in the last few years because it permits on-the-spot analysis and instant feedback to the performer, whereas film still requires development time.

Most of the data obtained from films are of a quantitative nature, such as acceleration and velocity. Kinetic data, such as torques and forces, can be derived from kinematic data.

Films can aid the coach in discovering potential dangers to athletes, such as poor body position or ill-timed movement sequences. Cardboard projections, called spines, can be attached to the athlete at various positions, especially the spinal column, to aid in detecting the potential dangers of compression and tension caused by specific changes in body positions at high torques.

Stroboscopic photography offers the advantage of projecting all the action on one plate so that the researcher does not have to search through many frames of film — a most tedious job. The disadvantage of stroboscopy is that there can be no overlapping or repetitious movements. Overhead stroboscopy is often used to analyze such activities as the golf swing; deviations from the ideal swing are easily observable from this position. Stroboscopy automatically produces a contourogram if light-sensitive tape is used to mark the subject's body.

In using videotaping or cinematography, it is important to take more than one exposure to be sure the athlete's normal patterns are recorded. Videotapes may be converted to films for more permanent records.

Expensive cameras and equipment are not needed. Cameras taking 64 fps are adequate for gross film analysis. The most common types of photography are as follows:

1. Single plate, single exposure
2. Single plate, multiple exposure or stroboscopy
3. Sliding film, multiple exposure
4. Cinema, frame exposure

A camera used in many laboratories is the Lo-Cam, which can film at 500 fps. At this speed a ball leaving the hand will be an easily observable sphere. The exact moment of release, the athlete's fingers, and small hand movements can be seen and analyzed.

When filming movements involving more than one plane, where multiple cameras are used, a timing device is necessary to synchronize the cameras. A conical timing device, which allows the time to be seen from more than one plane, can be homemade. However, for filming in one plane, a regular clock face is sufficient.

The backdrop should be of uniform color to permit filming the object to its best advantage. The camera should be placed at a right angle to the action being filmed so that the activity will proceed across the screen.

However, straight or head-on analysis is sometimes done, depending on the objective of the researcher.

A distance measure, consisting of any object of known dimensions, should be placed in the background. Each subject should also be numbered.

A film reader can be used to trace the developed film to obtain data. Film readers are available in many libraries and universities and are easy to operate, although tracing is time-consuming. One kind of tracing is a stick figure, which can be drawn even with little artistic ability. Joint movements, for example, can be analyzed from such a simple figure. In running, body lean, arm action, stride lengths, and the position of the center of gravity can be seen from stick figures, or contourograms. A contourogram can be broken down into phases, each of which can be studied separately.

Another area of research involves testing sports equipment. For example, placing a strain-gauge on a canoe paddle can help determine how much stress the paddle can take before it breaks. Hockey sticks can be fatigue-tested to determine their breaking point, and fencing weapons can be tested to determine the amount of impact they will have on the performer.

The coach may be the one who orders equipment and must explain if it fails. Before purchasing equipment, the coach should ascertain what kinds of tests the equipment has undergone and how safe that equipment is.

Field hockey provides a good example. Are mouthpieces necessary for players? Are face masks necessary for goalies? If so, should they be made like ice hockey masks? What types of shoes are best, now that field hockey is played on artificial surfaces and cleats are no longer necessary? How much do we know about the forces that shin guards can absorb? All these questions need answers that can be provided by action-oriented research.

A force platform is often used to obtain force-time histories or impulses, especially in the vertical or horizontal jump. These force-time histories can be used to analyze the subject's jumping pattern and to show such items as peak force produced, time in the air, timing of body segments, time necessary to generate force, and velocities. A coach, even an experienced one, could look at a jumper and never observe these particular things. But if the coach were also a researcher, she could have the athlete perform on a force platform and quickly determine imperfections of pattern that could be corrected by coaching.

Make-break switches, which are really one-hundredth-of-a-second chronoscopes and can be made very cheaply, are also used extensively in research. In swimming, for example, an athlete can be wired so that when she starts a racing dive she triggers one switch, and as she hits the water, she triggers a second switch to complete the circuit. The coach then knows the exact amount of time the athlete was in the air on a particular dive.

Electrogoniometry is another tool used extensively in physical education research. Electrogoniometers measure angles and can be attached to sports equipment or to people. Electrogoniograms (tracing from electrogoniometry) explore such questions as the following: Does the athlete take off at an optimal angle?Does she obtain maximal extension on the take-off? Does she "give" on landing or remain rigid?

Electrogoniometers can be waterproofed by wrapping them in balloons. Electrogoniometry can then be used to trace the angles of the knee and ankle during various swimming kicks.

Electromyography (EMG) is often used to study muscle action potentials generated during various activities. EMG can help the coach see what muscles are working and when they are working the hardest. Using both EMG and electrogoniometry simultaneously, the same swimming coach could tell at what angle of the knee or ankle the muscle involved was working the hardest. This information could have important implications for training that muscle.

In the past few years, computers have been used to analyze physical education data. They make film analysis much easier and more convenient. One well-known device used to prepare data for the computer is the graphic tablet. The researcher traces data points from the film with a sparking pen. The impulse of the sparking pen is picked up by two small microphones in the tablet frame. These impulses are then printed out as the X and Y coordinates of the points touched with the sparking pen. The microphones are also sensitive to the time lapse between the sparking pen touch and the impulse.

Such data can be processed as plots, which can be read very easily. Displacement, velocity, acceleration, center of gravity, and moment of inertia are some of the items that can now be calculated by computer.

The recent development of a new kind of computer output, a simulated 3-D model, could have great implications for studies of heat production. For example, infrared photographs could be taken of football players in full gear, and hot spots on the body could be identified. This type of output could also aid in determining forces produced or sustained by athletes.

While the instrumentation currently being used in physical education research answers many questions, it leaves many questions unanswered. When these are answered, they will give rise to still more questions. Some new questions under investigation are the lift in swimming, swimsuit resistance, and the ability of vaulting pads to absorb force. One old question, now being re-evaluated in light of newly developed track surfaces, is the efficiency of the stand-up start in track.

Who needs research? Everyone, from the small child just learning to run, to the high school athlete, to the professional female athlete of the future.

Who can do research? Almost everyone. If you have ever analyzed an athlete or searched for a better teaching method, you have, without knowing it, been a part of research.

ENDURANCE TRAINING FOR WOMEN

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Ten to fifteen years ago, the only women competing in distance running events were a few cross-country competitors who were considered eccentrics by most of the sporting world. Today they have become the "foremothers" of the growing numbers of women pounding pavement and paths for miles and miles each week. A majority of the current participants fall into the category of jogger, seeking exercise and pleasure from a 15- to 30-minute jog three to seven times a week. However, there has been a marked increase in the number of women training as distance runners, and most distance events are now open to men and women. Gone are the days when a woman had to sneak into the Boston Marathon.

The factual information related to the effects of endurance training on women is limited. Most training programs are relatively new; little data have been gathered; the availability of subjects is just beginning to increase.

PHYSIOLOGICAL CHARACTERISTICS OF ENDURANCE RUNNERS

Endurance events require that the athlete use the aerobic metabolic pathways. The greater the individual's ability to use oxygen — i.e., the greater the $\dot{V}O_2$ max — the faster the pace that may be maintained for an extended distance. It is not surprising, then, that a woman engaged in endurance training has a $\dot{V}O_2$ max higher than that of the average sedentary female. Values for the somewhat active female range from 30 to 40 ml/kg·min. Wilmore and Brown (1974) found a group of women distance runners of national and international caliber, aged 20 to 37, to have a mean $\dot{V}O_2$ max of 59.1 ml/kg·min. The highest value was 71.1 ml/kg·min, and the top three runners averaged 67.4 ml/kg·min. These values are comparable to those of male marathoners of national caliber. Plowman (1974) measured the aerobic capacities of various women athletes. Runners had the highest mean value, 60 ml/kg·min; followed by cross-country skiers, 58 ml/kg·min; swimmers, 52 ml/kg·min; skaters, 48 ml/kg·min; and gymnasts, 43 ml/kg·min. Plowman stated that the mean male $\dot{V}O_2$ max exceeded the female value by 23 percent in marathoners and 7 percent in 1500-meter freestyle swimmers. The highest value reported for any woman athlete has been 74 ml/kg·min for a Russian cross-country skier (1974). The young female runners observed by Raven and others (1972) had an average $\dot{V}O_2$ max of 49 ml/kg·min. However, these 12- to 18-year-old girls trained for and ran in events not exceeding one mile in length. Brown and others (1972) found that prepubescent female cross-country participants achieved V_{O_2} max of 55 to 56 ml/kg · min after a training program.

In these studies, the $\dot{V}O_2$ max was expressed per unit of body weight. Thus, body weight and, more importantly, the fat component of the total body weight affected the $\dot{V}O_2$ max achieved. The 59.1 ml/kg·min average for Wilmore and Brown's female runners was 15.9 percent lower than their male counterparts when expressed per unit of total body weight. The difference could be reduced to 8.6 percent by computing $\dot{V}O_2$ max relative to the lean body mass. The fat weight of each subject was subtracted from the total body weight to determine the individual's lean body mass. When $\dot{V}O_2$ was expressed per unit of lean body mass, the female runners were only 8.6 percent lower than the males. Thus, in Wilmore and Brown's study, body fat differences between males and females accounted for almost one-half the difference in $\dot{V}O_2$ max.

Most consider body fat to be detrimental to performance in endurance events. As Drinkwater (1973) pointed out, the total body weight, fat included, must be carried by the athlete as part of the total work load. The three top runners in Brown and Wilmore's study (1972) had a mean body fat of 7 percent similar to that found in male runners of comparable caliber and considerably below the normal sedentary female values of 23 to 30 percent. Their total group of 11 runners averaged 15.2 percent, including one runner having 35.4 percent body fat. Eighteen months later this runner set the women's world record for 50 miles; however, her body fat content at the time of the record was not known. Wells and others (1973) found that 13 to 19 percent body fat occurring at puberty tended to result in a decreased $\dot{V}O_2$ max. The maintenance of a low percentage of body fat during puberty would enhance endurance performance in the adult female.

BENEFITS OF TRAINING PROGRAMS

At any age an endurance training program increases the $\dot{V}O_2$ max. Brown and others (1972) noted an 18 percent increase in the $\dot{V}O_2$ max of 8- to 12-year-old female cross-country runners after six weeks of training. After 12 weeks the $\dot{V}O_2$ max had increased to a value 26 percent greater than the pretest. Eisenman and Golding (1975) compared the training responses of 12- to 13-year-old girls and 18- to 21-year-old women. The training programs consisted of three 30-minute running and bench stepping periods per week for 14 weeks. The girls increased their mean $\dot{V}O_2$ max 17.6 percent, and the women showed a 16.1 percent gain. In other words, the training effect was independent of age.

Kilbom's (1971) subjects ranged from 19 to 74 years of age. He found an inverse relation between age and the percentage of increase in $\dot{V}O_2$ max, which can be attributed to the normal decline in $\dot{V}O_2$ max with increasing age. All other factors being equal, it would not be possible for the older individual embarking on a training program to reach the same $\dot{V}O_2$ max as a younger person. Kilbom found that greater increases were noted in women with initially lower $\dot{V}O_2$ maxs and for women who trained at higher percentages of their $\dot{V}O_2$ max. The 17- to 28-year-old women trained by Fringer and Stull (1974) for 10 weeks on a bicycle ergometer gained 37 percent in $\dot{V}O_2$ max and noted a 63 percent increase in work output. A similar gain of 33 percent in $\dot{V}O_2$ max at PWC 170 was found by Hanson and Nedde (n.d.) in sedentary women who trained five days a week for eight months.

There is evidence (Astrand 1963; Brown and others 1972) that the response of prepubescent girls to endurance training is similar to or greater than that of adults. Only longitudinal studies can provide the data necessary to evaluate endurance training programs for prepubescent girls. Knowlton and Weber (1968) observed the effects of training up to 10 miles per day on a young woman runner. They concluded that the program was rigorous but not detrimental to the runner. Other studies (Hanson & Nedde, n.d.; Kilbom 1971; Knowlton & Weber 1968; Plowman 1974) have concluded that there were no sex differences in response to training. It is obvious that there are many questions to be answered regarding the effects, beneficial and/or detrimental, of a hard, overdistance training program on girls and women. The knowledge gap should close as more women join the ranks of participants and as facilities, coaching, and equipment become available to women.

EVALUATION OF ENDURANCE PERFORMANCE

Prediction of Potential

Although $\dot{V}O_2$ max is the physiological criterion most closely related to endurance performance, it may be directly measured only in a laboratory setting. Increases in $\dot{V}O_2$ max would indicate to a coach the success of a training program and would provide a physiological basis for predicting performance. (However, every coach must remember that many factors other than the physiological affect athletic performance.)

For mass testing or when laboratory facilities are not available, the Balke Twelve-Minute Run Test (1963) is a good field test to *estimate* $\dot{V}O_2$ max. Each girl is asked to cover as much distance as possible on a measured track or level course in 12 minutes. She is encouraged to establish a steady pace but is permitted to walk, if necessary. The girl is stopped at the end of 12 minutes and her distance recorded. The distance covered is divided by 12 to obtain meters/minute or yards/minute. Using Balke's formula, her $\dot{V}O_2$ max may be predicted:

$$\text{Predicted } \dot{V}O_2 \text{ max (ml/kg}\cdot\text{min)} = 33 + .178\ (\overset{\text{12 min pace}}{\text{meters/minute}} - 133)$$

Table I shows precalculated values.

Table 1. Balke Field Test
$\dot{V}O_2$ Max Predicted from Running Velocity

Running speed		pred. $\dot{V}O_2$
meters/minute	yards/minute	max(ml/kg·min)
100	109	27.1
120	131	30.7
140	153	34.2
160	174	37.8
180	197	41.4

200	219	44.9
220	240	48.5
240	262	52.0
260	284	55.6
280	306	59.2
300	328	62.7

For runners with paces greater or less than values shown in Table I, the predicted $\dot{V}O_2$ max will increase 1.8 ml/kg·min for each 10 m/min or 10.9 yards/min increase in pace.

When evaluating experienced runners, the time of the test should be increased to 15 minutes and the total distance covered divided by 15. All runners, especially the inexperienced, should be tested two or three times or until the predicted $\dot{V}O_2$ levels off. This is the pretraining value. This provision must be made for the inexperienced to learn to pace themselves for 12 minutes.

An estimation of $\dot{V}O_2$max is important in that it gives the coach a starting point for each individual, and it provides a simple field method for evaluating training effect.

Estimation of Training Intensity

Because there is a direct linear relationship between $\dot{V}O_2$ and heart rate, the heart rate can be used during training bouts to estimate the intensity of the bout. Optimally, heart rate should be monitored during the exercise. This is not practical for large groups and/or when telemetry equipment is not available. A field method is to count the pulse at the wrist or carotid artery for 15 seconds *immediately* upon stopping work and extrapolating it to a minute value. Karvonen (1957) has provided a formula for determining the minimal heart rate to provide a cardiovascular training effect. The runner should be training at a minimal heart rate, which is equivalent to the resting heart rate plus 60 percent of the difference between the resting and maximal heart rates, or

Training HR = Resting HR + .60 (maximal HR - resting HR).

The resting heart rate should be taken before activity commences and after a 10-minute seated rest. If the actual maximal HR is unknown, the average values reported by Astrand and Rodahl (1970) can be used:

AGE	10	20	30	40	50	60
MAX HR	210	200	185	175	170	165

Training will lower the athlete's maximal heart rate so that the highly trained endurance athlete may have a maximal heart rate up to 25 beats per minute lower than her untrained counterpart. However, the resting heart rate of the trained athlete will also decrease, so the difference between maximal and resting heart rates will remain nearly constant. For example, as a result of training the resting heart rate of a 20-year-old may decrease from 80 to 65, the maximal heart rate from 200 to 185 or 190. The difference remains about 120, but the minimal desired training heart rate drops from 152 to 137. A runner training at a consistent pace and distance each day would note a decreased exercise heart rate, indicating that there was a training effect. This decrease was demonstrated in Hanson and Nedde's study (n.d.) in which the pretraining HR for sedentary females at 14 percent grade on the treadmill was 171. After four months of training the mean HR of the group at 21 percent grade was 163.

Another guideline for estimating work intensity of extended runs (10+ miles) can be derived from the Balke Field Test (1975). Once the maximal speed (m/min or yds/min) has been determined during the Balke test, the coach may set the training pace between 70 and 85 percent of the maximal speed. For a runner averaging 200 m/min on the Balke Test, an extended run at 150 m/min (10.42 minute/mile) would represent 75 percent of the maximal pace.

IMPLICATIONS FOR TRAINING FOR ENDURANCE EVENTS

Assuming that there are no sex differences in the type of responses to endurance training (Drinkwater 1973; Hanson & Nedde, n.d.; Kilbom 1971; Pollock 1973), guidelines for endurance training can be taken from the research on male runners.

Kaufman and others (1974) found a relationship between the number of months of training and the finishing order in a marathon. They recommended that a marathoner run many miles over many months rather than a greater number of miles in fewer months. The distance runners observed by Costill and others (1973) trained at 60 to 80 percent of their $\dot{V}O_2$ max and were able to run at 91 percent of their $\dot{V}O_2$ max during competition.

In his review of the literature on quantifying endurance programs, Pollock (1973) indicated that the primary factors influencing the magnitude of the training effect were the intensity and the duration of the work. Frequency of training is a major factor only when the training is limited to a few weeks. The greatest improvement can be noted in those programs involving the greatest total energy output. That is, the endurance athlete will attain maximum benefits from training at a pace that represents a relatively high percentage of her $\dot{V}O_2$ max over as great distance as possible during each workout. The total improvement noted is also related to the individual's genetic endowment, the initial level of cardiovascular fitness, and previous exposure to endurance training programs. Participants in middle-age or older or those who have low initial fitness levels should avoid high intensity work during the first several weeks of a training program. Intermittent work, or interval training, may be beneficial to these groups, allowing the individual to achieve the same total energy output during a workout with less physiological stress.

Pollock stated that research shows the fitness improvement achieved was independent of the mode of exercise employed so long as intensity, duration, and frequency were held constant. Thus, the individual desirous of increasing her general cardiovascular fitness level may achieve her goal by running, swimming, or cycling.

SAMPLE TRAINING PROGRAMS

Included below are sample training programs to provide ideas for program planning. They illustrate a great diversity in training approaches. It

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should be noted that when Drinkwater and Horvath (1971) simulated track practice for 12- to 18-year-old girls on a treadmill, they found the girls worked above 80 percent of their $\dot{V}O_2$ maxs for most of the practice. Any coach having access to laboratory facilities could evaluate the quality of her workouts by a treadmill simulation of a typical workout.

Also note that the Waldniel Pure Endurance Method included below is very different from the others. It stresses distance work at a very low intensity (low training HR recommended). Each coach will have to base her training program on the starting levels, individual needs, and goals of her runners.

A. Foreman's developmental program for Falcom Track Club (1969)
   Sept. 1-Dec. 1, cross country running: long distance, speed work, hill work
   Dec. 1-Jan. 1, active rest. participation in other sports and games
   Jan 1.-Feb. 15, circuit training: for strength, flexibility, power
   Feb. 16-Mar. 30, Fartlek and repetition running: "speed play," run/jog or run/walk
   April 1-July 15, interval training-endurance: distances 1/4 to 2/3 or length of race, repeated until 2 to 3 times race distance is covered.
   July 16-Aug. 31, interval training-speed: 1/8 to 1/2 race length, pace faster than race pace.

Doris Brown's interval endurance workout for 800 meter race:

day	*warmup*	*distance*	*race*	*reps*	*rest*
Monday	1 mi. jog	440	65	3	jog 2 laps
		660	easy stride		10 min. jog
		75	fast stride	10	walk back
Tuesday	1 mi. jog	1320	3.35:0	2	10 laps jog
	Finish with 20 minutes of easy striding on grass				
Wednesday	1 mi. jog	660	1.35:0	2	5 laps jog
		220	fast stride	5	1 lap jog
	Finish by sprinting out five turns				
Thursday	1 mi. jog	330	45	5	2 laps jog
	Finish with 20 minute run through nearby park (hills)				
Friday	1 mi. jog				
	repeat Monday's workout				
Saturday	Extended run of 6 to 10 miles				
Sunday	Early morning run as usual . . . with complete rest in afternoon.				

B. General workout schedule for Francie Larrieu (1974)
   Morning: daily 4- to 7-mile run
   Afternoon: MWF - long runs; TTH - track (interval) workouts

C. General workout schedule for Nina Holmen (1975) 3000 m time: 8.55.2
   10 to 14 workouts/week with 30 to 60 minutes per session, year around.
   distance run: 80+ kilometers/week
   mornings: 5 to 8 kilometers; evenings: 10 to 15 kilometers
   steady runs mixed with fartlek and speed plus intervals during racing season

D. General workout pattern of Liane Winter (1975) 2:42:24 marathon
   daily long runs at a slow pace with a few speed workouts
   A Saturday or Sunday run up to 60 kilometers

E. Waldniel Pure Endurance Method (1971)

Daily training preceded by light jogging. Average daily training depends on the event:

event	*daily distance covered*
1,500 m	10 x race distance = 15 kilometers
3,000 m	7 x race distance = 20 kilometers
5,000 m	5 x race distance = 25 kilometers
10,000 m	1 x race distance = 42.2. kilometers
marathon	

For this method it is recommended that the athlete train at a heart rate between 80 and 130, without breathlessness.

SUMMARY

There is no evidence to indicate any difference between the male and female response to training programs; a female of any age can increase her cardiovascular fitness level and $\dot{V}O_2$ max through endurance training. There appear to be no detrimental physiological effects of programs involving more than 100 miles per week. However, more longitudinal research is needed to clarify the effects of severe endurance training programs on prepubescent girls. The average female embarking on an endurance program should not attempt continuous workouts of severe intensity and duration during the first few weeks. However, the athlete desiring maximum improvement in endurance capacity must train at work levels between 60 and 90 percent of the $\dot{V}O_2$ max pace over extended distances. The improvement will be directly related to the total energy output during training.

IMPLICATIONS FOR THE COACH

High levels of body fat appear to be detrimental to endurance performance. Most successful women distance runners have 5 to 15 percent body fat compared to average adult females having 23 to 30 percent.

A coach should assess the aerobic capacity of each athlete at the beginning of the training program. The workouts developed should "overload" the athlete by providing sustained exercise at 60 to 90 percent of her aerobic capacity. Periodic evaluation can assess the progress being made in the improvement of aerobic capacity.

Workout programs should provide a variety of experiences. Most distance runners alternate interval workouts with extended distance runs. Hard workout days should be followed by lighter days or a day off.

Champion endurance runners are born with the physiological potential for success, but it must be remembered that physiological capability is only one facet of the total athlete. Experience, race strategy, and mental attitude are important in the development of a distance runner.

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WHAT YOU EAT IS WHAT YOU GET

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"You are what you eat" is an adage that has particular significance to athletes and coaches. Unfortunately when advising athletes about their diets, coaches often rely on other adages and superstitions that are misleading, or expensive, and sometimes dangerous. Some of the common notions are as follows (American Association for Health . . . 1971):

1. Protein is the primary source of muscular energy.
2. No fats, fried foods, or oil dressings should be eaten by athletes.
3. No candy or pastries should be eaten during training; bread and potatoes should be restricted.
4. The pregame meal must include steak, the rarer the better.
5. Water intake should be restricted during practice. Suck on ice cubes only. Rinse the mouth with water; do not swallow.

Coaching has gained immensely from some areas of research. Let us examine what the area of nutrition can teach coaches. In particular, what advice can a coach give to ensure proper nutritional intake by an athlete during training? What guidelines should a coach instruct her athletes to follow regarding diet prior to and during competition to encourage maximum performance? The answers that coaches need can be stated simply, because the simple basics of good nutrition are the same for athletes as for us all.

GOOD NUTRITION ALL THE TIME

Everyone needs food in proper amounts to function efficiently. Nutritionists and physiologists suggest that the daily diet should include a proportion of approximately 45 percent carbohydrate, 40 percent fat, and 15 percent protein (Hursh 1972). Fad diets that deviate from these percentages should be avoided by athletes and nonathletes alike. Weight reduction through fad dieting usually results from reduced caloric intake and not from consumption of specific foods. If used over a prolonged period of time, fad diets may have such severe consequences as ketosis (abnormal increase of ketone bodies in the body from impaired metabolism), kidney damage, hypoglycemia, central nervous system disability, or even death. The best weight loss diet is one that maintains the nutrient balance but limits the total caloric intake. Increasing energy expenditure will also help deplete energy stores. Weight reduction should be done slowly over a period of time so as not to overtax the organs of the body.

Such fads as high protein-high fat diets, banana and skim milk diet, the macrobiotic diets, or the inches-off diet result in weight loss but do not provide directions for maintaining initial weight loss through good eating habits. Diets such as the macrobiotic diets that require an individual to eat less and less food and finally just ingest small amounts of brown rice are particularly dangerous.

For athletes, a normal mixed diet eaten at intervals to which the individual has become accustomed allows an athlete to be more efficient over a long period of time in terms of days (Hursh 1971). Nutritionists suggest that the diet include a daily intake of eight glasses of water, four servings of bread and cereal, two servings of meat or high protein, and two cups of milk. A coach should advise her athletes especially about the importance of a nutritionally adequate breakfast for maximum efficiency. It has been shown that people who eat breakfast maintain higher blood sugar levels through the day than do those who do not eat breakfast (Coleman et al. 1953). Breakfast eaters also showed an 80 percent increase in maximum work output over those who do not eat breakfast (Daum et al. 1950). Nutrition research leaves clear implications for the importance of eating breakfast to athletes seeking the best possible performance levels.

The practice of restricting the intake of bread, fried foods, and oily dressings during training does not seem to be substantiated by research. The body needs a certain amount of fat to carry the fat-soluble vitamins. Apparently the reasoning behind this practice came from the notion that protein was the main source of muscular energy and that athletes had trouble digesting fatty foods. However, as has been indicated, a daily diet requires approximately 40 percent fat and only 15 percent protein. It is agreed, however, that excess consumption of oily foods should be restricted in everyone's diet because they may be the cause of overweight and related problems.

BEFORE AND DURING THE GAME

The "carbohydrate loading" theory is the first exception to the principles of balanced diet. During mild exercise, carbohydrates are the main source of muscular energy; as the individual works harder, carbohydrates can be transformed into muscle glycogen. When an individual engages in strenuous workouts, the glycogen stores of the active muscles are depleted. To replace and build up muscle glycogen stores in preparation for the stress of competition, it has been suggested that distance runners and performers engaged in endurance activities deplete glycogen stores in the working muscles, then increase their intake of carbohydrates approximately 72 hours before competition (Astrand 1968). This practice is called carbohydrate loading. Along with carbohydrate loading, the severity of workouts is reduced in the 72 hours prior to competition to further assure increased glycogen stores. Cross-country skiers in Sweden and many long-distance runners have followed the carbohydrate loading practice for many years.

The carbohydrate loading theory is based in part on the work of Astrand (1968). He found that persons eating a high carbohydrate diet and riding a bicycle ergometer could continue peddling for a longer time period than persons on any other type of diet. Another favorable result of carbohydrate loading has been shown through the use of muscle biopsies, which reveal greater water retention of the cells for marathon runners who have eaten diets high in carbohydrates (Costill 1974). Such increased water retention is desirable for athletes in endurance events.

Regarding the pregame meal, coaches have written an additional chapter to Greek mythology. The myth about eating steak before competition dates back to early Grecian times when athletes who ate little meat were beaten by athletes on a predominately meat diet (Astrand & Rodahl 1970). Today it is a custom in the United States for teams to consume a pregame meal that includes steak ordered as rare as possible. Beef in this form resembles live muscle, and the ancient idea persists that you must eat muscle in order to develop muscle. It is becoming increasingly apparent through research, however, that you can save your money and allow the athlete to eat what she wants before a game without adverse effects (Hursh 1971). The time for the steak is after competition, win or lose.

In contrast to the high-protein pregame meal, some teams are using a high-carbohydrate meal. Some professional football teams and a very successful Illinois women's college basketball team are following this practice (Cohen 1973).

Another alternative for the pregame meal is a liquid meal, first used with some success for football players at the University of Nebraska in the late 1950s (Rose et al. 1961). Despite the advantages, the many positive reports, and the economy involved, the Nebraska team discontinued the practice when they found themselves in the midst of a losing season some time later. Liquid diets do have the advantage of eliminating digestive discomfort, particularly when athletes are under great stress.

The question of when to eat is often considered equally important as what to eat before competition. Most coaches agree that the pregame meal should be eaten three to four hours before the event and suggest that the stomach be empty during the athletic contest. X-ray studies have shown that athletes under stress take from two to four hours longer to digest a solid pregame meal than they normally would (Rose et al. 1961). For this reason, some coaches resort to liquid meals before competition. Many liquid meals are made from milk, a substance which has been accused of cutting an athlete's wind. Studies indicate that this is not the case. If milk is drunk immediately prior to competition, the only consequence the athlete may feel is a slight thirst (Hursh 1971; Rose et al 1961).

Since athletic competition is often accompanied by emotional stress, and since eating habits are individual in nature, the matter of when and what to eat before athletic competition may best be left to the discretion of the individual athlete.

WATER INTAKE

Finally, it is imperative that coaches discuss water intake with their athletes. The notion that water intake should be restricted during practice has resulted in unnecessary illness and could result in death from heat stroke (Hursh). A loss of 2 or 3 percent of body weight (2.5 to 3.5 pounds for a 120-pound woman) as a consequence of dehydration resulting from hard practice sessions or performance can lead to a significant reduction in athletic performance. Dehydration can occur not only outside in hot, sunny, humid climates, but also in gymnasiums when athletes are deprived of water during practice or competition. Water loss combined with work in high temperatures and humidity could lead to heat stroke, heat exhaustion, or heat cramps. Of the three, heat stroke is the most serious and can cause death. Heat exhaustion or heat cramps can be a warning of more serious things to come. Once an athlete has suffered heat illness, she is more susceptible to future attacks.

These complications occur most frequently when the climate is hot and humid, when water intake is low, and when athletes are not acclimatized. Part of the acclimatization process in hot weather is to maintain the osmotic balance in the body between water and body electrolytes (especially salt and potassium). To assure osmotic balance, frequent water breaks should be a standard procedure, and athletes should be allowed to drink water whenever they wish, with added encouragement from the coach. There is no such thing as being water-logged. People rarely drink enough water to replace their water loss through sweat (Hursh 1972). Sometimes athletes must be forced to drink water to replace what has been lost through sweating. Taking salt tablets to replenish salt loss is unnecessary if the athlete salts her food in warm weather, and it could be a dangerous practice if used over a prolonged period of time. The salt in the salt tablet cannot be absorbed when the body is deficient in water and will only further upset the body's osmotic balance. Large amounts of plain water at frequent intervals is the recommended practice. Salting of food, catsup on food, or an occasional tomato or banana for potassium replacement will maintain the electrolyte balance. The use of such commercial preparations as Gatorade may help maintain body electrolytes, but the preparations are not absolutely necessary. What is essential is that athletes be encouraged or required to drink large quantities of water both on and off the practice field.

The American College of Sports Medicine (1975) recently issued a position statement on the prevention of heat injuries. The purpose of the position statement is to alert sponsors of distance running events of the health hazards of heat injury and heat illness during distance running and to give preventative measures. The guidelines state that distance races of 10 miles or more should be conducted before 9 a.m. or after 4 p.m. on days when the temperature exceeds 80 degrees Fahrenheit and should not be run under conditions of high temperatures and high relative humidity. Race sponsors are urged to establish water stations, make sure fluids are administered, and be certain that race officials are able to recognize the signs and symptoms of heat illness. The importance is that physicians, physiologists, physical educators, and other health professionals recognize that heat illness is a potential danger that can be prevented.

SUMMARY

There are no magical tricks to the athletic diet. An athlete should eat a nutritionally balanced diet (45 percent carbohydrate, 40 percent fat, 15 percent protein) during training and in preparation for competition. A sound diet necessitates breakfast and includes minimal amounts of fat and high-sugar food.

The timing and content of the pregame meal should, in most cases, be left to the athlete. Some coaches may want to look into the use of liquid meals, especially if their athletes have problems with digestion or when events are closely scheduled and do not allow for meals. A high-carbohydrate meal may be warranted before prolonged and endurance competition.

Perhaps the most important ideas for coaches to stress are eating balanced meals and drinking enough water. Athletes and the general public can never drink too much water. Lack of food or nutritional imbalance may affect athletic performance. Lack of water may affect life.

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FEMALE SPORTS INJURY DATA: COLLECTION AND INTERPRETATION

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A vast number of female students are now participating in a variety of interscholastic and collegiate sports to obtain the assorted benefits associated with participation and training for participation. In doing so, they are accepting a reasonable risk of injury and assuming that those who govern and assist sport programs are using professionally defensible methods for keeping the risk reasonable.

Coaches, athletic directors, and rules committees are facing many decisions concerning sports safety problems with conflicting recommendations and without data to verify or refute respective contentions. Decision-oriented sports injury data on females essentially are incomplete, obsolete, or uninterpretable. Existing studies are confined to short-term investigations (usually one season), to a particular sport (usually basketball), to a particular area (usually no larger than one community), and/or to a particular injury (usually the knee).

This state of affairs exists because sports injuries and illnesses are not as readily adaptable to routine national reporting as other medical problems:

- They stem from an environment in which injury is expected.
- The athlete challenges the injury and the persons who evaluate and treat it because of the profound motivation to perform.
- The "health care system" for handling the athlete's injury is organized differently than for traffic, industrial, or home injuries.
- The criteria for evaluating an athletic injury are related more to performance impairment (time loss from participation) than to type of medical care (e.g., hospitalization, surgery).
- Formally trained medical records personnel are basic to hospitals and industry but not to sports.
- Organized sports programs for females have not yet stabilized in scope and intensity.

These factors make it difficult for decision-makers to be aware of normative data, prevailing factors, the influence of particular changes or trends, or the significance of a publicized occurrence or isolated study. They are stuck with opinion.

Despite these problems, courts and legislatures are calling for evidence of institutional accountability for the protection of the athlete from undue risk. The Occupational Safety and Health Act (OSHA), which has been functioning in industry since 1971, is edging toward the sports arena with its codes, inspections, and compliances. More recently, the Consumer Product Safety Commission (CPSC) entered this arena via its National Electronic Injury Surveillance System (NEISS). Further, federal legislation called for a national study of the sports injury problem.

The efficacy of applying OSHA's procedures and criteria to the athletic setting is seriously questioned. While CPSC is beginning to reveal its potential for serving the public's safety interests, the design of NEISS as an investigative mechanism for sports is appropriate to the sports scene in principle but not in access and capability. The "Forsythe Amendment," signed into law in August 1974, funded a study by the Department of Health, Education and Welfare (HEW) of the frequency of male and female athletic, intramural, and physical education injuries in schools and colleges during the 1975-76 school year; however, its investigative mechanism does not define particular sports or injuries. An interorganizationally planned mechanism (NAIRS) for obtaining continuous meaningful information on significant injuries and illnesses incurred by athletes, including females, was not precluded by the HEW study, and is the subject of this paper.[1]

NAIRS - PHASE I (CONCEPTUALIZATION)

Early in January 1974, a small group of individuals who collectively reflected the interest of national sports and sports medicine organizations affected by the preceding legislative activity were convened at a meeting, supported in part by the Pennsylvania State University and in part by the organizations represented, to discuss the potential merit of a conceptualized National Athletic Injury/Illness Reporting System (NAIRS). The essentials of the plan had been shared with the executive director of the National Athletic Trainers Association earlier in the year. Inherent in this approach was sensitivity to the preface of the Joint Commission on Competitive Safeguards and Medical Aspects of Sports' *National Football Injury Report–1970:*

> The data from the fall of 1969 was considered preliminary and developmental and therefore was not published....The changes in the reporting formats and an apparent lack of reliable definitions in 1970...have diluted the potential value of the present report.
>
> Also contributing to this dilemma has been an apparent fractionating of purposes and goals among those who compiled the form, and those who analyzed it. An unfortunate end result has been a mass of data with no one person or agency continuously responsible for the resulting report.

The outcome of the meeting was that the group agreed to serve as an advisory committee to NAIRS, which would be housed at Penn State until fully operational on a national basis. Marlene Adrian represents AIAW on this committee. The next day, the NCAA Committee on Competitive Safeguards and Medical Aspects of Sports voted to ensure continued progress by awarding a research grant to the Pennsylvania State University for covering the expenses of a second advisory committee meeting. Later in the day, the Joint Commission on Competitive Safeguards and Medical Aspects of Sports discontinued its impending committee activity along similar lines in favor of this plan.

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[1] The authors are directing the HEW study as well as NAIRS. Schools wanting to cooperate in NAIRS should contact Sayers J. Miller, Jr. at 102 Sports Research Building, Penn State University, College of Health, Physical Education and Recreation, University Park, PA 16802 (814-865-9543).

Later in January, consequently, the NAIRS advisory committee reconvened to assist in refining the details of the plan and the developmental steps toward its operational readiness. Consensus was reached on all essential considerations, and encouragement was given to the project director to pursue the funds necessary to bring the system and pilot year into operation.

WHAT IS NAIRS?

NAIRS is a surveillance system, a new mechanism for collecting meaningful athletic injury/illness data continuously in a nationally uniform manner. Surveillance, as in detective and spy stories, constitutes tailing the behavior and associations of a suspected culprit. It is a mechanism for obtaining information on such events as they occur. The analogy can go further in that surveillance is not in-depth investigation but is used to see when and with what focus an in-depth investigation is justified.

NAIRS is designed to be as much a service to institutions, with versatile capability and low-cost operations, as a research tool. Coded forms call for descriptive detail on illnesses and injuries that keep an athlete from participating in sport. All forms, codes and statistical analyses are oriented toward decisions in sports and the constraints of scientific inquiry. It is not enough to know the frequency of knee injuries or the relative frequency of different kinds of injuries. Decision-makers need to know patterns of circumstances at the time of injury and the actual effects of a particular course of remedial action. They also need to be protected from unsubstantiated conclusions from poor or incomplete data.

Athletic injury experiences notoriously vary from year to year in a given school as well as between schools. One year's findings do not constitute a baseline. Further, because sport constantly changes, any study is obsolete within a year or two after its completion. Only when "trend-lines" or patterns are established through continuous surveillance can it be learned whether a particular experience lies within a normal range of variation or demonstrates a shift in frequency. For this information, NAIRS analysis distinguishes the potentially significant minor injury or illness (the athlete is back within a week) from the demonstrated significant injury. For perspective, NAIRS can also classify significance by medical management (surgery, bed rest), nature (recurrence, complication), and action taken (hospitalization, other).

NAIRS—PHASE II (EARLY EXPERIENCE)

A variety of organized sports — male and female, school and college — have been followed by NAIRS since fall 1974, on a developmental basis. In time, physical education, intramurals, and recreational programs could be accommodated as well. The same set of NAIRS forms is used for all sports, enabling a school to shift from one sport to another without logistical problems. A recorder handbook with instructions and the respective codes for each sport is given to each participating school. By a series of simply coded forms, NAIRS-I connects within the computer many potential factors of influence in its search for patterns of injury and patterns affecting a type of injury. Injury rates can be expressed epidemiologically using squad size; number of games; number of practices; type of participant (substitute, star, or regular); and age, height, and weight. Rates can further be expressed by proportion of athletes using a particular product, playing a particular position, engaged in a particular activity, and so on. School size, coach characteristics, and other descriptive information also can be used for examining contentions. NAIRS-I is the designation given to the prototype system in operation. NAIRS-II, an abridged version of NAIRS-I, has been developed as well for sports with few injuries and/or those not related to product safety. NAIRS-II asks fewer questions but uses the same codes as NAIRS-I. Table I displays the female sports being followed in 1975-76. Other adaptations of NAIRS-I are in process.

Table 1
1975-76 NAIRS Female Sports Participation

	COLLEGE			*HIGH SCHOOL*		
Sports	*NAIRS-I*	*NAIRS-II*	*Total*	*NAIRS-I*	*NAIRS-II*	*Total*
Baseball	0	1	(1)			
Basketball	19	7	(26)	2	2	(4)
Fencing	2	1	(3)			
Field Hockey	14	6	(20)	0	1	(1)
Gymnastics	11	3	(14)	0	1	(1)
Ice Hockey	1	1	(2)			
Lacrosse	3	1	(4)			
Softball	8	2	(10)			
Swimming	5	3	(8)			
Tennis	6	4	(10)	0	1	(1)
Track & Field, Indoor	3	0	(3)	0	1	(1)
Track & Field, Outdoor	5	1	(6)	0	1	(1)
Volleyball	11	3	(14)	0	2	(2)
Cross Country	6	2	(8)	1	2	(3)
Crew	1	1	(2)			
Golf	3	2	(5)			
Judo	2	0	(2)			
Squash	1	0	(1)			
Water Polo	1	0	(1)			
	102	38	(140)	3	11	(14)

DATA REPORTS, CONFIDENTIALITY, AND COSTS

With NAIRS-I, unchanging information (for that season) on the sport and the athletes is collected once and computerized. At the end of each week, throughout the season, all reports of injuries incurred are submitted to NAIRS with a weekly transmittal sheet identifying further information on number of games, practices and average squad size that week. This avoids the research problem of relying on post-season memory. It also provides midseason awareness of injury patterns. NAIRS-II constitutes a log of injuries to be kept during the season and submitted at the end of the season. Any athletic trainer, student trainer, or other conscientious personnel associated with the institution's varsity program can comply with either NAIRS-I or NAIRS-II procedures with a minimum of orientation. The forms and their codes are designed to make the work as painless as possible yet yield information necessary for decisions.

NAIRS-I is designed to return periodic reports to each participating school: (a) monthly reports, which display inventory information of its experiences to date; and (b) seasonal reports, which display a summary of its experiences at the end of a given sport season's end. Both reports will include for reference and perspective the average experience of all schools (of its type). (NAIRS-II will provide only seasonal reports.) Once NAIRS is fully operational, rules committees and qualified investigators as well as participating schools will be able to obtain current data of relevance within a day of the inquiry. This service will begin when there are enough funds for continuing the computer preparation process.

At no time will the experiences of a particular school be released to another. Further, at no time will NAIRS know the identity of any athlete in the system. Each school is given a log sheet for giving each athlete a NAIRS code number; only the code number is forwarded if that athlete is injured.

Until early experiences and a thorough systems analysis of the data processing design are completed, operating costs cannot be determined. NAIRS is designed for continuity through versatility and frugality. Further, it is a nonprofit activity with capabilities for receiving supportive grants. Operational cost will be affected by the number of schools participating plus the degree of success in locating supportive funds; however, a school year's subscription to the service for all the sports the school wishes to cover should be between $50 and $100.

WHY NAIRS?

Sports programs are accustomed to budgeting for recording performance minutiae (e.g., charting rebounds) but not injury information. NAIRS was predicated on the assumption that a practical and meaningful mechanism for following health problems in sports would be supported by sport decision-makers. No credible data means no perspective for episodic studies reflecting the magnitude of the injury problem in a sport or for differing opinions on rules or equipment changes. Because of the invisible variability in injury definitions and patterns, it is customary for one school to think that its experiences, however interpreted, are typical of all schools. Preliminary analyses of 1974-75 NAIRS data already refute that assumption.

INDIVIDUAL AND TEAM BIORHYTHMS AND PERFORMANCES IN THE 1975 AIAW NATIONAL BASKETBALL CHAMPIONSHIPS

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Biorhythm theory, first explored and postulated in Europe at the turn of the 19th century, has recently begun attracting widespread attention in the United States in a variety of areas. Present knowledge indicates that humans are profoundly affected by many cycles. There have been definite short- and long-term cycles involving heart rate, hormonal activity, sleep patterns, energy levels, moods, intellectual "ups and downs," accident proneness, and medical recoveries. Scientists commonly talk about "biological clocks" when referring to many of these rhythmical changes in the human body.

The biorhythm theory includes three cycles: (a) a physical cycle that affects physical strength, stamina, endurance, energy, resistance, and vitality; (b) a sensitivity or emotional cycle affecting nerves, intuition, moods, feelings, affections, confidence, irritability, and creativeness; and (c) an intellectual cycle affecting mental alertness, memory, logic, reasoning power, reaction rate, intelligence, and ambition.

The physical rhythm has a 23-day cycle, with 11½ days in the positive zone (when an individual feels best and accomplishes the most physically) and 11½ days in a negative phase (when an individual tends to be in a physical "slump"). The sensitivity rhythm has a 28-day cycle, with 14 days in a positive emotional and creative zone and 14 days of a negative period. The 33-day intellectual rhythm is also split, consisting of 16½ days when the individual's mental response is more adequate and 16½ days when the individual's mental response is functioning at a reduced capacity.

Days when an individual is switching from a positive to a negative phase or from a negative to a positive phase are "critical days." These are days when the unexpected can happen. If two rhythms are crossing to another zone at the same time, there is a "double critical day"; if all three rhythms are switching on the same day, it is a "triple critical day."

In Germany, a study involving biorhythmic curves disclosed that 83 percent of workers' accidents occurred on critical days (Bio-rhythms 1974). A bus company in Japan charted biorhythm curves of 500 drivers and reported a 50 percent decrease in accidents the first year it initiated the practice of notifying drivers of their critical days (Bio-rhythms 1974; Thommen 1973). A hospital in Switzerland recorded medical crises and found that more than five times as many brain strokes and cardiac infractions occurred on patients' critical days as on all other days combined

(Bio-rhythms 1974; Thommen 1973). Recently, biorhythms were plotted for the pilots of the TWA jetliner that crashed into a northern Virginia mountain in December 1974. According to the Washington *Post* of Sunday, February 2, 1975, TWA Captain Brock was in negative physical and emotional periods and First Officer Kresheck was in a negative phase physically, emotionally, and intellectually. Also, pilots Hatem and White, who flew their small private plane into the American University radio tower in January 1975, were both experiencing emotional critical days. In addition, White's physical and Hatem's physical and intellectual cycles were in the negative period (Zito 1975).

Within the past five years, some interest has been shown in the use of biorhythms in athletics. Individual biorhythms have been plotted and compared in individual performances in physical feats; biorhythms of team players have been plotted and combined to form "team" biorhythms.

California biorhythmic researchers, Michael Wallerstein and Nancy Roberts (1973), predicted with overwhelming accuracy the outcome of several college and professional football games in 1972 and 1973. They charted the biorhythmic cycles of players to be involved, combined these to team cycles, and forecase offensive and defensive team performances from these team curves.

On December 23, 1972, running back Franco Harris of the Pittsburgh Steelers made what many consider the play of the century. In the last few seconds of the AFC playoff games against Oakland, Harris made an almost unbelievable catch and run for touchdown. At the time, Harris was in the middle of a super-positive phase mentally, physically, and emotionally. Prior to that date, on December 10, 1972, the biorhythm graph showed a triple negative low physically, mentally, and emotionally. On that day, against one of the weakest teams in the league (Houston), Harris failed to gain 100 yards for the first time in seven weeks (Wallenstein & Roberts, 1973).

Several other studies involving athletic figures in golf, baseball, boxing, and track, to mention but a few, have been conducted. An amazing amount of individual performances seem highly related to the biorhythmic standing of the individual at the time of each event (Thommen, 1973).

PURPOSES

The primary purpose of this study was to compare the individual and team biorhythms of the female competitors involved in the AIAW National Basketball Championships (March 19 to 22, 1975, Madison College, Harrisonburg) with individual and team caliber of play and outcome of games. A second purpose was to determine if injuries or accidents (if they should occur) are correlated with critical days and/or negative phases of the individual's biorhythm curves.

PROCEDURE

Birth dates were obtained for each of the players from the 16 teams competing. (The biorhythm theory postulates that many definite cycles start at the moment of birth.) Subjects participating did not know about the study. There was no contact with the players or demand upon their time, energy, or skill. Coaches were neither informed of the reason for data collection nor given any results prior to, during, or after the competitive period.

Taking the year, month, and day of birth of each competitor and using the sine-curve method published by Psi Rhythms, Inc., Dayton, Ohio, physical, emotional, and intellectual biorhythms were plotted for each member of each team. Values for the physical, emotional, and intellectual cycles were obtained from published tables and mathematically calculated to determine the three-cycle phase of each player at the time of the tournament. Figure 1 is an example of a typical individual's biorhythm chart. (For a detailed description of how biorhythms are plotted, the reader is referred to the first two citations in the list of references.)

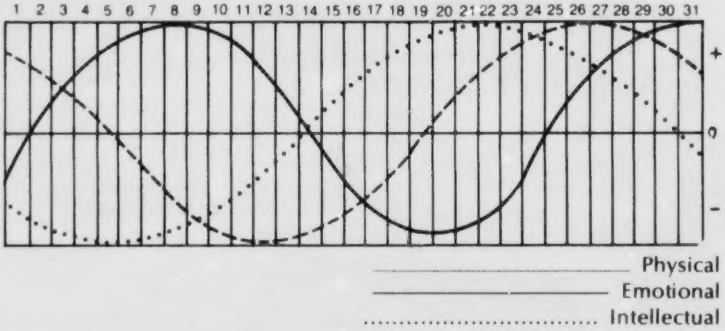

Figure 1. Typical Individual Bio-rhythm Chart.
(Person was on double critical day on March 14 when P and I cycles were both changing zones. During tournament (March 19-22), individual was at I high and P low, with an E critical day on 19th, but moving to positive zone for additional three days of tournament.)

Team biorhythms were obtained by plotting each team member's physical curve on one chart, emotional curve on another chart, and intellectual curve on a third chart. From these, a "line of best fit" was used to determine the team curve for March 19 to 22.

Game record sheets were obtained and selected individual performances matched to biothythm phases. All very good or very poor performances and extreme biorhythms (highs and lows) of individuals were noted and compared to the appropriate biorhythm or performance.

Players were given good or poor rankings based on their individual season averages. If a player scored five or more points or rebounded three or more above her season average she was given a good performance rating. If a player scored five or more points below the season average, she was given a poor rating. The subjective judgments of the tournament director and the director of sports information at Madison College were also used in rating the players. These two sources had to be relied on almost exclusively in determining performance level of team playmakers and lower scores. Team biorhythms were compared among all teams, with special emphasis placed on the top six seeded teams and winners bracket.

RESULTS AND DISCUSSION

First Round

First round results were almost totally predictable from seeding and team records for the year. But scoring and team performance of each game throughout the tournament were more predictable when biorhythms were included. Seven out of the eight games played in the first round resulted in wins and losses that matched biorhythms (and team records and seeds). The only exception was the fourth seed, which biorhythmically should have won in the first round. They were at a much higher level physically and emotionally than Team E. (According to the biorhythm theory, the physical and emotional cycles are much more important in athletic performance than the intellectual cycle.) The leading scorer of the fourth-seeded team was on a physically critical day, however, and did not perform to her season averages.

The game between Team J and the second-seeded team was considered a toss-up. The individual biorhythms of the top scorers and playmakers of the two teams offer some data from which to draw conclusions. The top scores from both teams were about equal in their biorhythms. The main playmaker of each team, however, showed extreme biorhythms. The Team J playmaker was in a triple negative phase, whereas the main playmaker from the second-seeded team was in a triple positive phase.

The individual biorhythms in the first round show that 14 players were in a triple positive phase. Eight performed above their season averages, four below their averages, and two did not play. Seven players were in a triple low. Five performed below their season average, one played above her season average and one did not play. One individual was on a triple critical day. Her performance was extremely poor in comparison to her season performance.

Quarterfinals

In the quarterfinals, the fifth-seeded team was slightly below the first-seeded team in the physical biorhythm and well below them in the emotional and intellectual biorhythms. Many coaches and members of the press considered the fifth-seeded team to be the one to watch as the potential winner of the entire tournament. One All-American from the fifth-seeded team was at a triple low but performed well above average in the tournament. The other All-American was at a double low physically and emotionally and performed below average. Two other members of the team were at a triple low. Three players from the first seeded-team were at a triple positive phase. Two scored above their season averages, and one scored below the season average.

Team E had two players in a triple positive phase and two players in a triple negative phase. All performed adequately.

Team D was very low physically compared to Team E and slightly lower emotionally. Individual top scorers from Team D performed below average. Team E won.

Team H and the third-seeded team were equal in their biorhythms as teams. Individual biorhythms among the starters of each team gave Team H the advantage, but performances and biorhythms matched well in only five individual cases.

Second seed and sixth seed were also equally matched biorhythmically. The top scorer of the second-seeded team was at a high physically and emotionally, however, and scored 42 points, and the top playmaker of the second-seeded team was at a triple high and played superbly.

Semifinals

The semifinals found Team E going against the first-seeded team and the second-seeded team going against the third-seeded team. Both games were considered to be toss-ups by the tournament director and the press. Seed one was higher physically and much higher intellectually and won, 63 to 54. (Both teams were approximately the same emotionally.) Seed two was slightly higher in all three areas and won, 71 to 68.

Finals

In the finals, both teams were approximately equal physically and emotionally. Seed one was higher intellectually. Individual biorhythms, however, showed that the top playmaker of seed two was a triple high and the top scorer was at a double high physically and emotionally. The top playmaker and All-American from seed one was a double low physically and emotionally. Seed two won, 90 to 81.

Individual Biorhythms and Performance

Individuals who were in a double or triple positive stage (N=42), double or triple negative stage (N=29), or on a critical day (N=25) were analyzed in relation to their performance by use of chi-square (Table 1). A significance of 0.001 was obtained ($x^2=34.18$). There was a higher-than-expected number of individuals at a double or triple high who performed above average. There was a higher-than-expected number of individuals at a double or triple low who performed below their season averages. On critical days, players performed above average or below average in a higher-than-expected number of cases. (Fortunately, there were no seri-

Table 1.
Individual Biorhythms and Performance

	Bio-Rhythms		
Performance	*High*	*Low*	*Critical Day*
Above Average	33	3	11
Average	3	5	1
Below Average	6	21	13

ous injuries reported during the tournament, and that comparison could not be made.)

Team Biorhythms and Performance

Teams were compared (by chi-square) using biorhythmic level and performance (Table 2). A significance of 0.025 was obtained ($x^2=9.0$). Teams higher biorhythmically were winners at a higher-than-expected rate. (The x^2 value may be slightly inflated because of low numbers.)

Table 2
Team Biorhythms and Performance

	Bio-Rhythms		
Performance	*Higher*	*Lower*	*Same*
Won	9	3	3
Lost	3	9	3

CONCLUSIONS

Overall, starting with the first round and following team outcomes (winner's bracket) and performances of individuals who were at an extreme biorhythmically or on a critical day, approximately 85 percent of individual and team biorhythms matched individual and team performances.

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FEMALE SPORT PARTICIPATION PATTERNS

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Current issues related to women and sports have prompted a proliferation of interest in women's athletics, the female athlete, competition for women, and the legal implications of equal opportunity for sport participation. This interest has been accompanied by conferences devoted entirely to women and sport and by research publications and textbooks on the topic. It is striking, however, that despite the interest in women and sport, relatively few empirical data pertaining to the female athlete (or participant) have been made available — with the exception of personality and self-image studies. Furthermore, few studies have used a social science perspective. Little is known about the female sport participant relative to the nature of her sport involvement — what factors influence her sport participation, who she is, and how she can be characterized within a sport context.

Recently a study (Greendorfer 1974) was undertaken to investigate the process of female socialization into sport. Specifically, the research was designed to determine the factors that influence women to become actively involved in sport. The female sport participant was characterized by using a theoretical social learning paradigm, previously used on male athletes only. A fixed-alternative questionnaire was administered to 585 women participants in the Wisconsin Women's Intercollegiate Athletic Conference (WWIAC) during the 1973-74 academic year; the returns were subjected to various statistical procedures, and the following are a few of the general descriptive findings.

THE SUBJECTS

The respondents ranged in age from 17 to 42; the mean age was 19.4 years. Although the women were enrolled in a variety of academic programs, 45 percent of the sample were physical education majors. Of the group, 31.79 percent were freshmen, 31.97 percent sophomores, 9.66 percent juniors, and 15.38 percent seniors.

The distribution according to year suggests that the recent advent of women's sport programs at the college level has not been followed by a "storming of the gates" by women of all ages. Thus, opportunity alone might not be a critical factor accounting for participation; rather, sport participation might be a result of *both* opportunity and conscious or unconscious sport socialization efforts which begin quite early in life. Further results from the data support this notion and will be discussed in a later section.

TYPES OF SPORTS

Since the respondents in this study were not "elite" athletes,[1] many sports were represented and the women varied in both skill level and degree of involvement. Thus, the sample is one of a heterogeneous group of sport participants rather than of elite athletes. Table 1 contains the number and percent of respondents according to specific sport.

Table 1. Number and Percent of Returns by Each Sport

Sport	Number	Percent
Badminton	45	7.7
Basketball	71	12.1
Cross Country	13	2.2
Diving	7	1.2
Gymnastics	158	27.0
Swimming	87	14.9
Tennis	46	7.9
Volleyball	158	27.0
TOTAL	585	100.0

The differential participation according to specific sport could be accounted for by two factors: (a) some of the colleges in the WWIAC did not offer every sport; and (b) certain sports could be more popular than others. Although it might be expected that team sports would contain the greatest number of participants, only volleyball reflected this expectation. In contrast, gymnastics contained as many participants as did volleyball, which might support the popularity contention.

The information obtained from the questionnaire tapped total sport involvement; thus, multiple sport participation was possible. Therefore, the respondents were classified according to "sport type." A criterion of 70 percent, based on total sport participation hours, was used. Table 2 depicts the four general categories of sport types after application of this criterion. The "mixed sport" category was created because several women participated in a combination of sports that could not fit into the 70 percent participation time criterion.

Table 2. Number and Percent of Sample by Sport Type

Type of Sport	Number	Percent
Individual	236	40.3
Dual	79	13.5
Team	214	36.6
Mixed	56	9.6
TOTAL	585	100.0

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[1] This term, frequently used in sport sociology literature, refers to a select group of highly skilled performers who have achieved recognition for their athletic success. Usually such athletes have participated in high-level competition (e.g., Olympic or World Games).

CHILDHOOD PARTICIPATION CHARACTERISTICS

Approximately 34 percent of the respondents became involved in sport or some form of physical activity before the age of 5; 45 percent between the ages of 6 and 8; 15 percent between 9 and 11; and 5 percent between the ages of 12 and 14. It is interesting to note that approximately 79 percent were participating by the age of 8. All the respondents were actively involved in sport by the age of 14.

When socializing agents responsible for first sport involvement were considered, 39.5 percent of the women indicated that the family was the first agent; whereas 31.1 percent learned in their neighborhood, 23.6 percent through the school, 3.4 percent through the community, and only 1.7 percent became involved through private clubs. Of interest is the fact that the school was not the initial agent for sport involvement for at least three-fourths of the participants. Conversely, family and peers (neighborhood) accounted for the initial introduction into sport for approximately 71 percent of the respondents.

NATURE OF SPORT PARTICIPATION DURING THREE LIFE STAGES

During childhood the number of sports in which the women participated ranged between two and five, with 55.9 percent of the sample participating in two to three sports during this stage. Approximately 24 percent participated in four to five sports. Only 11 percent participated in one sport during childhood, whereas 9 percent participated in six or more sports.

During adolescence this participation pattern shifted somewhat, but not significantly, toward an increased number of sports. Almost 44 percent indicated participation in two to three sports, while 29 percent participated in four to five. Approximately 11 percent indicated one sport only, and 13 percent mentioned six or more. Thus, the most noticeable shift was toward the upper extreme.

When compared to the two younger age ranges, the adult pattern reflected a significantly different pattern of sport participation. At this stage 96.5 percent participated in only one WWIAC sport, while [illegible].4 percent participated in two or three WWAIC sports. When non-WWIAC (e.g., non-Conference, recreational, city leagues) sport involvement was considered, less than half the sample (42.6 percent) indicated such participation. Therefore, it appears that participation, when measured by number of sports, is greatest during both childhood and adolescence. Specialization seems to occur at the college age, and the number of sports decreases accordingly.

Information relative to the number of hours in which the women participated during each of the three life stages is presented in Table 3.

Table 3. Hours Respondents Spent in Sport Participation

Life Cycle State	One Hour or Less	Two Hours	Three or More Hours
Childhood	26.7%	38.7%	34.7%
Adolescence	22.2%	48.6%	28.4%
Today	7.9%	52.7%	39.0%

As can be observed from this table, the majority of the respondents participated in sport two hours a day at each stage, the percentage in this category steadily increasing with advancing age. A substantial shift can be observed between childhood and adolescence. Also noticeable is the percentage of respondents who participated three or more hours a day. Although this number decreased somewhat during adolescence, a greater percentage participated three or more hours a day during adulthood than at any other stage. Thus, participation does not appear to decrease over the life cycle. Perhaps such a pattern is because of the regular basis on which team practices and coaching are scheduled. The percentage who participated one hour or less a day — which markedly decreased by the adult stage — could also add support to this notion.

Weekend sport participation demonstrated a different pattern, however. During childhood 54.5 percent participated for three or more hours, while only 21.2 percent and 16 percent did so during adolescence and adulthood, respectively. Thus, the commonly held belief that sport participation time is inversely related to age was demonstrated when weekend sport participation patterns were examined.

NATURE OF FIRST SPORT INVOLVEMENT

The majority of the respondents (78.1 percent) said their first sport was a team sport, while 20.2 percent indicated an individual sport. This finding was not surprising, however, as the nature of childhood games and activities emphasizes group activities and would tend to predispose participants at this age to team sports.

SELF-EVALUATION MEASURES

In addition to questions that pertained to actual sport involvement, several items were devoted to self-ratings in comparison to other women. Table 4 presents the self-evaluation of respondents when they compared their degree of participation to that of other women of the same age.

Table 4. Self-ratings of Participation Compared to Other Women at Each Stage of the Life Cycle

Self-Ratings	Childhood	Adolescence	Present
Well above average	27.2%	49.1%	35.7%
Above average	37.1%	38.6%	49.6%
Average	27.9%	8.9%	13.5%
Below average	6.0%	3.1%	1.2%
Well below average	1.5%	.2%	0 %

From this table it can be observed that the majority of respondents considered their participation either well above average or above average when compared to their peers throughout their life cycle. Most noticeable, however, is the fact that more respondents rated themselves well above average at the adolescent stage than at the college stage, the latter representing a stage of sport specialization.

Table 5 presents the results of the self-ratings of ability. Similar to the self-evaluations on participation, the respondents considered their ability well above average or above average when compared to their female peers. These ratings increased at the adolescent stage, but, although still higher than at childhood, at the college age there is a sizeable decrease in the well-above-average rating. In fact, this particular rating is lower than at any other stage. Thus, similar to the ratings of participation, ratings of ability reflected an upward shift as age advanced. It appears, however, that adolescence, not adulthood, is the period of highest self-evaluations.

Table 5. Self-ratings of Ability Compared to Other Women at Each Stage of the Life Cycle

Self-Ratings	Childhood	Adolescence	Present
Well above average	25.6%	31.8%	15.2%
Above average	43.4%	51.6%	60.3%
Average	26.3%	15.2%	22.9%
Below average	3.1%	1.2%	1.5%
Well below average	1.2%	0 %	0 %

Table 6 contains the self-evaluations relative to degree of sport involvement. These ratings also reflect similar trends to those displayed in self-evaluation of participation and ability.

Table 6. Self-ratings of Degree of Involvement Compared to Other Women at Each Stage of the Life Cycle

Self-Ratings	Childhood	Adolescence	Present
Well above average	22.1%	44.3%	32.7%
Above average	35.6%	38.3%	48.9%
Average	34.5%	14.9%	16.2%
Below average	5.6%	2.2%	2.2%
Well below average	1.9%	0.3%	0 %

A shift toward higher ratings occurred with increasing age, and again, adolescence appears to be the stage of the highest ratings. Naturally, it is entirely possible that the respondents underrated their own ability, involvement, and participation; nevertheless, their pattern appears to be consistent across the life cycle regardless of the existence of this phenomenon.

BACKGROUND MEASURES

The respondents were primarily from middle-class families, although all social classes were represented. Among the fathers of the group, 54 percent had some college or professional preparation beyond the bachelor's degree; 30.6 percent were high school graduates; while only 14.9 percent had some high school or less.

Father's occupation was coded according to Duncan's Index of Occupational and Socioeconomic Status (Duncan 1961), a widely used instrument that provides an index for each of the occupations in the detailed classification of the 1950 United States Population of Census. This index was divided into three groups corresponding to low, medium, and high. According to these classifications, 72.8 percent of the participants came from a background of medium and high socioeconomic status. The highest category contained 44.6 percent of the sample and included professional-managerial, business, or technical-engineering occupations.

In addition to the data pertaining to social class, information relating to religious background was also available. Approximately 39 percent of the sample were Catholic, 57 percent were Protestant, and only 1.2 percent were Jewish. This pattern, instead of reflecting religious background of female sports participants, could possibly be a reflection of the religious composition of the state of Wisconsin.

The majority of the respondents came from cities ranging from 10,000 to 100,000 in population. This pattern remained fairly consistent over the life cycle.

Ordinal position in the family has been considered a significant factor in female sports participation (Portz 1973). Since siblings are close in age and often interact in play groups throughout the socialization years, they are an important structural variable. Portz (1973) considered both the sibling-similarity hypothesis, derived from modeling theory, and the sibling-opposite hypothesis to explain sports participation. Although she favored the former proposition, no empirical data were presented to support either hypothesis.

Some data rendered in the present study are related to these theoretical considerations. However, ordinal position and presence or absence of siblings were not primary considerations in this investigation. First of all, the mean family size for the female participants was 3.26 siblings. Among the participants, 26.7 percent were first-born or only children; 53.5 percent had older brothers, while 20.3 percent had no older brothers; 46.3 percent had older sisters, and 17.5 percent had no older sisters. In addition, 23.1 percent were the youngest in the family. From this data, it appears as if the female participant is just as likely to have older brothers as older sisters, and perhaps she is more likely to be a middle child rather than first born or youngest.

Further examination of the birth-order data revealed an interesting and unexpected finding. A chi-square analysis of association indicated that there was a statistically significant relation between the presence of older sisters (but not older brothers) and the type of sport in which the respondents participated. This result, which indicated a significant chi-square at the 0.05 level, seems to be contradictory to a widely held belief that female team sport participants would be more likely to have older brothers than would individual or dual sport participants.

SUMMARY

The purpose of this paper was to present information that both characterized the female sport participant and portrayed her participation patterns. It should be remembered that the women in this study were not elite athletes; rather, they were sport participants who represented a heterogeneous group that differed in both skill level and degree of sport involvement.

In summary, it appears that the female participant in intercollegiate sport comes from a medium-sized city, comes from a middle-class or better background, and is initiated into sport by her family or through peers in her neighborhood. Her hours of participation time do not decrease with age; however, there is a decrease in the number of sports in which she participates, perhaps to allow for sport specialization. Her first sport is a team sport, but her adult sport may not be and is not predictable from her first type of sport involvement. She considers herself above average or better when compared to her peers in ability, degree of involvement, and in participation. Moreover, her highest self-ratings occur at the adolescent, not the adult stage.

This was an exploratory examination into active sport involvement patterns of female participants. Although several descriptive findings were revealed, much more information is needed. It is hoped that further empirical endeavors will accompany the theoretical notions currently advanced in the literature on women and sport.

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THE SOCIOLOGICAL PERSPECTIVE OF FEMALES IN SPORT

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From a sociological standpoint, the study of girls and women in sport is a much-neglected area of research. That they have been studied at all is more a commentary on the anomalous nature of women's sport than a recognition that sportswomen and their sport is a worthy and fruitful area of scholarly investigation

In fact, of 13 recently published texts and anthologies whose focus is the sociology of sport, only three have a separate chapter or section devoted to an examination of female involvement in sport. As shown in Table 1, only one other text contains a special section on the female role in sport within a chapter dealing with racism and discrimination. This material is less than 3 percent of the total content. The percentage of "fringe articles" — that is, those that either alude to the role of women in sport or report studies that included females in the sample — is also negligible. Of more significance is that only one of the texts in Table 1 was edited by a woman, and of some 200 unique articles in the anthologies, fewer than one-tenth were authored or co-authored by women. Based on the available evidence, there is no question that women athletes are not truly represented in studies and literature pertaining to the sociology of sport.

Table 1. Analysis of Articles Pertaining to Women in Selected Sociology of Sport Texts

Text or Anthology	Separate chapter or section section	Section within a chapter	Number of "fringe" articles per total
Loy and Kenyon (1969)	No	No	3/36
Kenyon(1969)	No	No	2/9
Luschen (1970)	No	No	3/12
Dunning (1972)	No	No	1/17
Hart (1972)	Yes	No	1/31
Stone (1972)	No	No	1/13
Edwards (1973)	No	Yes	—
Talamini and Page (1973)	Yes	No	2/31
Sage (1974)	Yes	No	2/29
Ball and Loy (1975)	No	No	2/12
Ibrahim (1975)	No	Yes	—
Yiannakis et al. (1976)	Yes	No	3/39
Landers (1976)	No	No	1/16

Unfortunately, the editors of sport sociology texts were and often still are at a loss to locate suitable material on women for inclusion in their volumes, because there has been very little original research or scholarly writing in that area. The reader familiar with Jan Felshin's section, "The Social View," in Gerber's *The American Woman in Sport* (1974); the section "Sociological Considerations" in Harris's *Women and Sport: A National Research Conference* (1972); or the relevant sections in Volumes I and II of the *DGWS Research Reports: Women in Sports* (Harris 1971 & 1973) has fairly well covered the available literature with the exception of several master's and doctoral theses, unpublished papers, and a few published articles.

THE NATURE OF SPORT SOCIOLOGY

Why is there so little material and original research on the sociological aspects of girls and women in sport? To answer this question, we must first examine the sociology of sport, specifically its past and present perspectives.

A relative newcomer within the social sciences, North American sport sociology has been evolving as an area of academic study for perhaps seven or eight years at most. Page (1973) gives its pervasive sociological themes as sport, society, and culture; sport in "mass society"; sport and social differentiation; the social organization of sport; and the culture of sport. Although it might be presumed that a sociological perspective on girls and women in sport would be inherent in each of these themes, it has been conspicuously absent. It is also interesting that the one theme (social differentiation) that perhaps lends itself best to analysing women's involvement in sport is surprisingly devoid of references to women. Gruneau (1975) points out that like all aspects of social life, sport has been greatly influenced by the institutionalized divisions and inequalities that serve to differentiate society. To understand the nature of sport, one must come to grips with the various social distinctions that exist between classes, between ethnic and racial groups, and more importantly in this context between the sexes. Since scholarly discussion on the topic of sport and social differentiation has begun only recently, little of this work relates to women in sports.

The sport sociologists whose work is subsumed under one or more of the five pervasive themes have invariably been male, and only now are female sport sociologists with sufficient training and interest beginning to turn their attention to a serious study of women in sport within a sociological framework. It is important to note, however, that a mere increase in the number of researchers with a particular interest in the social significance of females in athletics will not necessarily mean a concomitant increase in our knowledge. It will still be necessary to contend with the sexism and intellectual bias that permeate the social sciences.

BIAS WITHIN SOCIAL SCIENCE

Cultural beliefs and social practices are sexist if they are premised on the superiority of one sex, usually the male, and the accompanying masculine values. In discussing sexism within the social sciences, Stoll (1974) points out that female academics are as productive as their male counterparts with regard to publishing, consultation work, and professional society involvement, but since they are not employed in the elite institutions, they are excluded from the "club context" prevalent in academic disciplines. The result is that their contribution to the professional literature is, for the most part, unrecognized. More devastating perhaps is the sexism prevalent in the intellectual activity of social science. For example, in its literature the word *man* is used to encompass "woman," not just for convenience but in definition as well. The results of studies with male samples are frequently generalized to both sexes, thereby giving rise to erroneous conclusions. The effect is to focus perpetually on the activities of men, with vague and often inaccurate generalizations to the activities of women.

Not only will the researcher who decides to study some sociological aspect of females in athletics have to contend with the sexist ideology of the social sciences, he or she must also recognize that within the discipline of sociology, the subdiscipline of sport sociology has received very little recognition. It is still struggling to gain acceptance as a legitimate field of study.

SOCIOLOGICAL ANALYSES OF WOMEN IN SPORT

There are few sociological analyses of women in sport, even though the volume of literature both on sport and on women is increasing rapidly. We have seen why the sociology of sport literature is, for the most part, devoid of references to women and certainly of attempts to explain the social significance of women in sport. One would expect that the ever-increasing volume of literature and studies dealing with the sociology of sex roles or the sociology of women would examine the subject, if only from the perspective of leisure. But women's leisure and, more specifically, sport have been virtually ignored by the editors of anthologies on women, less so by the authors of books about sex roles. Either the authors and editors of these volumes feel unqualified to write about sport and leisure, or they dismiss it as unrelated and unimportant to the real issues underlying social differentiation and inequality. For instance, Elizabeth Janeway, in *Man's World, Woman's Place* (1971), writes that just as women's skills, once necessary for feeding and clothing mankind, have deteriorated into hobbies, so too have men's skills and prowess, such as hunting, degenerated into sport. She goes on:

> They have become adult play: leisure-time activities which imitate the realities of work. For children, such play is a necessary part of learning to live. In maturity, it a substitute for living.

Anthologies such as Safilios-Rothschild's *Toward a Sociology of Women* (1972), Huber's *Changing Women in a Changing Society* (1973), or Stephenson's *Women in Canada* (1973), which are fairly typical of readers used in an increasing number of women's studies courses, do not discuss aspects of women's leisure or the involvement of women in sport. Original works on women are few, and although such books as Stoll's *Female and Male* (1974) or Chafetz's *Masculine/Feminine or Human?* (1974) —

which examine male-female differences from the perspective of socialization and social structure — contain passing references to sport, there are no scholarly analyses of the female role in sport contained within the sociological literature on women.

The two most scholarly theoretical analyses of women in sport from a sociological perspective are Felshin (1974) and Willis (1973). These two papers are important contributions to the sociological literature on female sport involvement because they are theoretical analyses concerned with meaning, values, and social explanation. Neither Felshin nor Willis makes any attempt at scientific rigor, because their concern is solely with a theoretical explanation of the cultural meaning of sport. As Willis explains:

> The approach accepts the obvious differences in sports performance between men and women, accepts that cultural factors may well enlarge this gap, but is most interested in the manner in which this gap is understood and taken up into the popular consciousness of our society. In this perspective the fact of the gap is incontrovertible, but it is an *'inert fact,'* socially speaking, until we have explained the colossal *social* interest in it.

The articles by Felshin and Willis are important also because they are written from two quite different perspectives and yet in many ways support similar conclusions. Felshin writes from the feminist position, suggesting that the participation by women in sport is viewed as either "rational and desirable or as a fairly ubiquitous social problem" thus creating an interactive dimension between woman on the one hand and sport on the other, more concisely called a dialectic. Felshin argues that in reality the woman in sport is a social anomaly both because her behavior runs counter to the acceptable norms of feminine demeanor and because, according to men, her very participation tends to downgrade and denigrate the sport itself. The feminist position wishes to change all this, arguing that the woman in sport does not need to apologize for her participation because, as Felshin puts it, "the normative stereotypes for women are oppressive and antithetical to the development of human actualization."

Willis' thesis, written from an essentially Marxian viewpoint, is that "sport reflects a crucial, central feature of our culture; anxiety about sex roles." Accordingly, this sex-role anxiety manifests itself in social differentiation between the sexes, with male domination the most prevalent — a belief that is vital to the functioning of the capitalist economy. One ideology that pervades the capitalist system is that women are different and inferior; therefore, because they cannot participate equally with men, women in sport merely reinforce the existing ideologies.

SOCIAL COMMENTARIES

While the articles by Felshin and Willis are the only pure sociological analyses of women in sport, there remains an ever-increasing number of articles and papers that could be classed as journalistic social commentaries on the current role and status of women in sport. Much of this literature is reportorial, concerned more with facts and examples illustrating discrimination and sexism in sport rather than an analysis of why this is the case. Such articles as the three-part series by Gilbert and Williamson in *Sports Illustrated* are a good example of this approach; the interested reader may wish to pursue some of the references listed below.

Batten, J. Something to cheer about. *Homemaker's Magazine* 8, no. 5: 1973, 9-33.

Bellavance, M. and Bellavance, L. Sexism: rampant on the slopes? *Skiing* 25, no. 4:1972.

Deford, F. Now Georgy-Porgy runs away. *Sports Illustrated* 40, no. 16: 1974, 26-37.

Edmiston S. The gym suit blues: Changing the odds against women in sports. *Redbook* 142, no. 3: 1974, 69-70, 123-126.

Edwards, H. Desegregating sexist sport. *Intellectual Digest* 3: 1972, 82-83.

Felshin, J. The triple option — for women in sport. *Quest* 21: Winter 1974, 36-40.

Franks, L. See Jane run! *Ms.* 1, no. 7: 1973, 98-100, 104.

Gauthier, L. The second sex fights back. *Amateur Sport* 4, no. 3: 1973, 8-10, 34.

Gilbert, B. and Williamson, N. Sport is unfair to women. Part 1, *Sports Illustrated* 42: 1973, 88-89.

Gilbert, B. and Williamson, N. Are you being two-faced? Part 2, *Sports Illustrated* 42: 1973, 44-54.

Gilbert, B. and Williamson, N. Programmed to be losers. Part 3, *Sports Illustrated* 42: 1973, 60-73.

Gilbert, B. and Williamson, N. Women in sports: A progress report. *Sports Illustrated* 43, no. 5: 1974, 25-31.

Hart, M. Sport: Women sit in the back of the bus. *Psychology Today*, Oct. 1971, 64-65.

Hoffman, A. Running for gold. *MacLeans* 88, no. 2: 1975, 31-33.

Howell, R. Women's sport: The awakening. *CAHPER Journal* 41, no. 2: 1974, 14-16.

Hult, J. and McKnight, D. Competitive athletics for girls - We must act. *Journal of Health Physical Education & Recreation* 45, no. 4: 1974, 45.

Peterson, R. The coming boom in girls' sports, *Seventeen*, Feb. 1975, 76-77, 146.

Sales, B. She's just one of the guys. *Today's Health* 49, no. 4: 1971, 19-22.

Ulrich, C. She can play as good as any boy. *Phi Delta Kappan* 40, no 2: 1973, 113-117.

Weiss, P. Women athletes, In P. Weiss, *Sport – A Philosophic Inquiry*. Carbondale, IL: Southern Illinois University Press, 1969.

Zeigler, S.G. Self-perception of athletes and coaches. In D.V. Harris, ed., *Women and Sport: A National Research Conference*, University Park, PA: The Pennsylvania State University, 1972, pp. 293-305.

RESEARCH FINDINGS

It evident that the sociological study of female involvement in sport is just beginning, and to attempt a summary of research findings at this stage is difficult indeed. Nevertheless, one can identify those areas for which there has been at least tentative investigation and those in which substantial research is necessary. These are grouped under several broad themes, without attempt to discuss the findings or their implications.

Socialization into and via Sport

How do young girls become involved in sport in the first place? How important is the environment, their biological and genetic predisposition? What sort of socialization results from playing games and sport?

We know that sports participation has an important positive function in the development of masculine identity but a negative function in the development of female identity. This fact alone goes a long way toward explaining differential sport socialization among males and females; nevertheless, we do not have a definitive answer to the following question: Do boys and girls become differentially involved in sport because they are treated differently, or do boys and girls receive different encouragement to take part in sport because they demonstrate a contrasting predisposition to become involved from the beginning? Put simply, how do nature and nurture interact in the socialization process? One way to answer this question would be to examine the way in which biology and environment *interact* to produce the optimal conditions necessary, but not always sufficient, for the development of athletic potential among females.

Thus far, most of the work has been done on the nurture side. A good place to begin is to examine the literature on sex differences in the play behavior of young children. Here we find that the similarities between sexes are greater than the differences. One difference is that boys are more vigorous in their childhood play than girls and display greater physical energy. From a very young age, boys are more aggressive than girls. Almost universally, this behavior is tolerated in boys but firmly discouraged in girls, a phenomenon usually explained in terms of learning, training, and cultural influences, but this does not mean that there cannot be a biological origin. This interplay between the biological and social factors must be understood.

Sport involvement among females, particularly adolescents, relates directly to their conception of appropriate sex-role behavior. To understand the nature of sport socialization, we must come to grips with the factors operating in sex-role socialization. As Stoll (1974) points out, sports and games are meaningful for sex-role socialization in several ways. Our society tends to view some games as gender-specific. For example, body-contact sports, such as football, are considered "masculine," and for the most part girls are excluded from these sports; consequently, they do not develop the same skills and attitudes as do boys. Children who violate expectations and participate in games considered inappropriate for their sex have to resolve the situation with regard to the meaning of gender for themselves. Games may provide an opportunity for children to engage in activities considered inappropriate in the real world. For instance, most girls are allowed to compete quite freely on the playground but not as easily in real life. Play and games provide peers with an opportunity to develop their own standards and rules of behavior. Thus, if we accept that games and sport represent microcosms of society, then it is through the participation in ludic activities that the girl can learn about her role in the social order. We know little about how this learning occurs.

How important is her family, the school, her peers in the socialization of the young girl and adolescent into the role of sport participant? Again, our knowledge is rather meager, but it is probable that for a girl the family and peer group play a more decisive role in her sport socialization than does the school. Family interaction effects are important, particularly if the young girl has several older brothers. Still, we know little about the *relative* importance of the three major socializing agents and exactly how they interact in the total sport socialization process. Following are some references on this theme:

Beisser, A.R. The American seasonal masculinity rites. In A.R. Beisser, *The Madness in Sports,* New York: Appleton-Century-Crofts, 1967

Bettelheim, B. Growing up female. *Harper's,* Oct. 1962, 120-123.

Greendorfer, S.L. *The Nature of Female Socialization into Sport: A Study of Selected College Women's Sport Participation.* (Doctoral dissertation, University of Wisconsin). Ann Arbor, MI: University Microfilms, 1974, #74-27738.

Hauge, A. The influence of the family on female sport participation. In D.V. Harris, ed., *DGWS Research Reports: Women in Sport,* vol. 2, pp. 17-26. Washington, DC: American Association for Health, Physical Education, and Recreation, 1973.

Helanko, R. Sports and socialization. In N.J. Smelser and W.J. Smelser, eds., *Personality and Social Systems.* New York: John Wiley & Sons, 1963.

Herron, R.E. and Sutton-Smith, B. *Child's Play.* New York: John Wiley & Sons, 1971.

Kennedy, L. Mother-daughter relationships and their influence on female sport socialization. Master's thesis, University of Alberta, 1975.

Kenyon, G.S. and McPherson, B. Becoming involved in physical activity and sport: A process of socialization. In G. Lawrence Rarick, ed., *Physical Activity: Human Growth and Development.* New York: Academic Press, 1973.

Knox, W.E. and Kupferer, H.J. A discontinuity in the socialization of males in the United States. *Merrill-Palmer Quarterly of Behavior and Development* 7, 1971, 251-261.

Koch, H.L. Sissiness and tomboyishness in relation to sibling characteristics. *Journal of Genetic Psychology* 88: 1956, 231-244.

Landers, D.M. Sibling-sex-status and ordinal position effects on females' sport participation and interest. *Journal of Social Psychology* 80: 1970, 247-248.

Lewis, M. Culture and gender roles, there's no unisex in the nursery. *Pyschology Today* 5, no. 12: 1972, 54-57.

Lewis, M. Sex differences in play behavior of the very young. *Journal of Health, Physical Education, Recreation* 43, no. 6: 1972, 38-39.

Portz, E. Influence of birth order, sibling sex on sports participation. In D.V. Harris, ed., *Women and Sport: A National Research Conference,* pp. 226-234. University Park, PA: The Pennsylvania State University, 1972.

Sherif, C.W. and Rattray, G.D. Psychosocial development and activity in middle school (5-12 years). Paper presented at the National Conference and Workshop on the Child in Sport and Physical Activity, Queen's University, Kingston, Ontario, May 1973.

Stoll, C.S. Play and games. In C.S. Stoll, *Female and Male Socialization, Social Roles, and Social Structure*, pp. 90-97. Dubuque, IA: Wm. C. Brown, 1974.

Sutton-Smith, B. and Rosenberg, B.G. *The Sibling*. New York: Holt, Rinehart & Winston, 1970.

Yoesting, D.R. and Burkhead, D.L. Significance of childhood recreation experience on adult leisure behavior: An explanatory analysis. *Journal of Leisure Research* 5, no. 1: 1973, 25-26.

Sport Involvement

It is of the utmost importance to understand why some women choose sport and others do not and why some females drop out of sport at an early age whereas others continue for a lifetime. Of the information we possess about female sport motivation, *ex post facto* survey studies have provided much of the data but generally have failed to show a clear causual relationship between the chosen variables and female involvement in sport.

For example, in the 1974 study by Hall, virtually all of the explained variance in the present level of sport involvement among the women comprising the sample (more than 1,200 from the United Kingdom and Canada) was accounted for by a small number of variables, mainly the activity level when younger, the interests and participation of one's present family, and certain situational factors such as the complexity of a woman's life-cycle stage. This means that the high degree of association between, for instance, present involvement and past involvement is misleading, simply because both variables have common causes. These unknown and unmeasured causes could be any number of things: the extent and quality of school physical education experiences; the influence and sports participation of one's childhood and adolescent peer group; the general availability of sporting opportunities in one's past; and perhaps the most important of all, one's physical and psychological predisposition for athletic activity, some of which is most certainly biological in origin.

Longitudinal case studies would contribute a good deal more to our understanding of why some females choose to engage in sports and some do not. They would also help us to understand why some excellent female athletes drop out of sport, sometimes having achieved a very high level of performance. This is not to say that *ex post facto* survey studies should be discontinued (although taken collectively they provide no clear evidence of the antecedents of female sport involvement); on the contrary, they are especially useful for "theory trimming," and providing they maintain a high methodological sophistication and rigor, they should generate hypotheses that can be tested more thoroughly through in-depth, longitudinal case studies.

Attitude is a relatively unimportant determinant of female sport involvement. Women who are not interested in the more competitive aspects of sport do not harbor negative attitudes toward it, and even if these attitudes are slightly less than favorable, they do not appear to be the real deterrent to participation. What is of far greater importance is a woman's present situation and life-cycle stage. If her constellation of roles is complex — e.g., wife, mother of preschool children, and part-time worker outside the home — then she generally views her own leisure as unimportant and rarely makes it a priority item.

Following are references dealing with sport involvement:

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Emmett, I. *Youth and Leisure in an Urban Sprawl.* Manchester, England: Manchester University Press, 1971.

Furlong, B. Participation in physical education by women university students. *British Journal of Physical Education* 5, no. 6: 1974, 21-24.

Gerstl, E. Leisure, taste and occupational milieu. *Social Problems* 9: 1961, 56-63.

Ginzberg, E. *Life Styles of Educated Women.* New York: Columbia University Press, 1966.

Greendorfer, S.L. *The Nature of Female Socialization into Sport: A Study of Selected College Women's Sport Participation.* (Doctoral dissertation, University of Wisconsin). Ann Arbor, MI: University Microfilms, 1974, #74-27738.

Hall, M.A. A feminine woman and an athletic woman as viewed by female participants and non-participants in sport. *British Journal of Physical Education* 3: 1972, 43-46.

Hall, M.A. Congruence between a "feminine woman" and an "athletic woman" as a predictor of female sport involvement. Paper presented at the First Canadian Congress for the Multidisciplinary Study of Sport and Physical Activity, Montreal, Quebec, Oct. 1973.

Hall, M.A. Women and physical recreation: A causal analysis. Ph.D. dissertation, University of Birmingham, England, 1974.

Hall, M.A. I am not athletic by nature. *ATA Health and Physical Education Council Bulletin* 12, no. 1: 1974, 16-24.

Hawk, J.M. The relationship between attitude and participation in physical activity of eighth grade girls. Master's thesis, Pennsylvania State University, 1970.

Hobart, C.W. Active sports participation among the young, the middle-aged and the elderly. *International Review of Sport Sociology* 3-4, no. 10: 1975.

Kenyon, G.S. The significance of adult physical activity as a function of age, sex, education, and socio-economic status. Paper presented at Midwest Convention of AAHPER, Detroit, April 11, 1964.

Kenyon, G.S. Explaining sport involvement with special reference to women. Proceedings of Fall Conference, Eastern Association for Physical Education of College Women, Lake Placid, New York, Oct. 1969.

Komarovsky, M. Social life and leisure. In *Blue-Collar Marriage,* chapter 14. New York: Random House, 1964.

Murphy, B.E. Participation of married women in physical recreational activities as a function of socio-economic status and family life cycle stage. Master's thesis, University of Alberta, Edmonton, Alberta, 1969.

Nye, F.I. Employment status and recreational behavior of mothers. *Pacific Sociological Review* 1: 1958, 69-72.

Petrie, B.M. Education for leisure: A gap between ideology and practice. *CAHPER Journal* 38: 1972, 3-12.

Richardson, D.A. Women and Physical Activity: A Sociocultural Investigation of Primary Involvement. (Doctoral dissertation, University of Georgia). Ann Arbor, MI: University Microfilms, 1975. No. 75-8201.

Richardson, D.A. and Hall, M.A. Women and physical activity: A cross-national perspective. Paper presented at the Canadian Association of Sport Sciences Meetings, Edmonton, Alberta, Sept. 20-Oct. 2, 1976.

Searls, L.G. Leisure role emphasis of college graduate homemakers. *Journal of Marriage and the Family* 28: 1966, 77-82.

Toogood, R. A survey of recreational interests and pursuits of college women. *Research Quarterly* 10: 1939, 90-100.

Yoesting, D.R. and Burkhead, D.L. Significance of childhood recreation experience on adult leisure behavior: An explanatory analysis. *Journal of Leisure Research* 5, no. 1: 1973, 25-36.

Sport and Femininity

Some of the sociological literature on women in sport stems from a belief that women athletes experience a social conflict between the desire to participate and achieve in sport and the desire to fulfill appropriate feminine sex roles. However, what little social data there are show that women athletes do not differ from other women in terms of how they view their feminine role. It is possible, therefore, that a dichotomy between feminine expectations and sport involvement does not exist for the female athlete. Either she has resolved the problem of social conflict, or what is more likely, it did not exist in the first place.

There is also a prevailing social view that if a woman is a dedicated athlete, she is probably unfeminine. Researchers continue to administer masculinity-femininity tests to female athletes, generally showing that in a few catgeories at least, they have significantly lower and fewer "feminine" scores and higher and more "masculine" scores than other women. What is usually forgotten is that masculinity-femininity scales are merely social barometers of existing cultural factors that determine the concepts "masculine" and "feminine" in the first place.

Following are some references on the subject of sport and femininity:

Bell, Catherine. Conflict, the child of proficiency in women's tennis. *Lawn Tennis*, Feb. 18, 1972.

Boslooper, Thomas. Physical fitness and femininity. A paper presented to the American Association for the Advancement of Science, Dec. 1968.

Brown, R.E. *A Use of the Semantic Differential to Study the Feminine Image of Girls Who Participate in Competitive Sports and Certain Other School-Related Activities.* (Doctoral dissertation, Florida State University). Ann Arbor, MI: University Microfilms 1965, no. 65-15.

Landers, D.M. Psychological feminity and the prospective female physical educator. *Research Quarterly* 41: 1970, 164-170.

Metheny, E. Sports and the feminine image. *Gymnasion* 1, no. 4: 1964, 17-22.

Metheny, E. Symbolic forms of movement: The feminine image in sports. In *Connotations of Movement in Sport and Dance,* pp. 43-46. Dubuque, IA: Wm. C. Brown Co., 1965.

Ogilvie, B.C. The unanswered question: Competition, its effect upon femininity. Paper presented to the Olympic Development Committee, Santa Barbara, CA, June 1967.

Robinson, Paul D. Physical activity and femininity. *British Journal of Physical Education* 4, no. 4: 1973, 59-60.

Small, C. A comparison of feminine role perceptions of selected college female team and individual varsity athletes and non-athletes for themselves and "the average woman." Master's thesis, East Stroudsburg State College, 1973.

Zoble, J. Femininity, achievement and sports. In D.V. Harris, ed., *DGWS Research Reports: Women in Sport,* vol. 2, pp. 34-36. Washington, DC: American Association for Health, Physical Education, and Recreation, 1973.

Sport and Delinquency

Generally we believe that athletes tend to be less deviant in their behavior than do nonathletes, and what little research there is on the subject supports this view. With one exception, however, all of the research has been with males, primarily those of school age. One study (Buhrmann 1971) investigated the relation between athletic participation and deviant behavior in females. Sex differences were few, leading Buhrmann to conclude that high school girl athletes, like their male counterparts, are less deviant than nonathletes and that deviancy among athletes declines as they progress through high school. More revealing, however, is the fact that the profiles of deviants and athletes were in complete contrast. As Buhrmann put it:

> Deviants come from a socioeconomic background where education is not highly valued and rewarded, they have lower educational aspirations and levels of achievement, they participate less actively as well as passively in school activities and hold positions of leadership in few school and out-of-school clubs, their friends' values reflect and reinforce their own, and while they date considerably, their status with the opposite sex and peers as well as teachers is low. Almost the reverse is true for athletes.

We still do not know, however, if athletics acts as a deterrent to delinquency. The fact that athletes appear to be less deviant than nonathletes is probably a result of selection, since participation in competitive athletics is usually chosen by the conformer, the individual who generally complies with the established values of society (see, for example, the study by Straub and Felock, 1975). We need to understand, far better than we do, the preventive and rehabilitative effects of athletic participation.

Among studies on sport and delinquency are the following:

Buhrmann, H.G. Athletics and deviancy. Paper presented at the Third International Symposium on the Sociology of Sport at the University of Waterloo, Waterloo, Ontario, Aug. 22-28, 1971.

Straub, W.F. and Felock, T. 1975. Attitudes toward physical activity of delinquent and nondelinquent junior high school age girls. *Research Quarterly* 45, 1: 21-27.

Sports and the Media

Felshin (1974), writing about the media coverage of women's sports, stated:

> There are, obviously, some recent countertrends, but generally it is still true that if the evidence of coverage and attention to women's sport was used as a criterion, the conclusion would be that either only one or two outstanding women compete in sport at all, or that women do compete, but when they do, it is always in a nonserious and trivial way.

She is probably correct, although we do not have much in the way of evidence to prove it. A few graduate theses and unpublished papers have assiduously made content analyses of the sports pages in newspapers and the articles in sports magazines. With few exceptions, they find the amount of coverage devoted to women's sport to be minimal, which merely confirms the obvious. Nevertheless, they are useful, particularly insofar as they shed light on the image presented by the media of the woman athlete. It is through the description of this image that we may come to a better understanding of the social significance and meaning of female sport involvement

Following are some studies of coverage of women's participation in sport:

Abinanti, A. Communications media and women in sports. *Journal of Health, Physical Education, and Recreation* 42: 1971, 69.

Berlin, P. The media: Perceptual "double-agents." In J.A. Murray, ed., *Sports or Athletics: A North American Dilemma*. Windsor, Ontario: Canadian-American Seminar, University of Windsor, 1974.

Kennedy, L. and Leveille, L. Women, sport, mass media: Trends and status of women's sport as reflected by the *Edmonton Journal*, 1916-1974. Unpublished paper, University of Alberta, 1974.

Kirkpatrick, C. Getting into the picture. *Sports Illustrated* 42, no. 16: 1975, 85-96.

Lippincott, H. Male chauvinism at Candlestick Park. *The San Francisco Bay Guardian*, Dec. 22, 1971, p. 5.

Schrodt, B. Changes in the status of women's sport in Canada as reflected by newspaper coverage. Unpublished paper, University of Alberta, 1975.

FUTURE DIRECTIONS

The sociology of women in sport should be studied within the context of social differentiation. Almost all areas of social life — such as occupational and educational opportunity, political behavior, marriage and family, sexual beliefs and practices, leisure patterns, and most certainly sport — are influenced and affected by the institutionalized inequalities of society (Page 1973). Although sexual differentiation is not institutionalized to the same degree as class, racial, and ethnic differentiation, it still remains the basis for a major social division within society. Discriminatory practices abound in sport, because the belief that sport is a male preserve coupled with the realities of sexual differentiation continually enforce the "second sex" status of the woman athlete. Yet, beneath the rhetoric angrily denouncing sex-based discrimination in sport, there is no searching analysis of why this should be so. Sociologically speaking, the phenomenon has not been studied to any great extent. Perhaps, however, we would be wise to examine the whole question from a historical perspective first to understand better our present situation.

Sociological research into female sport involvement has been conducted almost exclusively on the female in competitive sport rather than in recreational sport. Consequently, we need to examine the role that sport and physical activity plays in the lives of "ordinary" women. Why, for so many women, is sport an insignificant aspect of their lifestyle? We would be wise to stop assuming that theirs is a negative attitude toward sport and physical activity and examine the real deterrents to their athletic participation. We should study the institutions of marriage and the family, the assumptions upon which they are based, and the restricting roles that women play within them. We would then perhaps come closer to understanding sport motivation or the lack of it among ordinary women.

When investigating the antecedents of female sport involvement, we simply cannot continue to ask "why," because behind every "why" lurks another one (see Berlin 1974). Somehow we have to select a starting point.

A question posed earlier in the discussion of sport socialization was "Do boys and girls become differentially involved in sport because they are treated differently, or do boys and girls receive different encouragement to take part in sport because they demonstrate a contrasting predisposition to become involved from the beginning?" There is strong evidence to suggest that it all begins before birth, and if so, we need to be much more concerned with the interplay between biology and environment than has been the case in the past. Whatever the approach, it must in certain respects be multidisciplinary within a unifying framework, one which we have only begun to design. And we must pay far more attention than we have to the sophistication and rigorousness of our research methodology. For whatever reasons, researchers have not been impressive in their methodology, nor thave they shown any real awareness of the diverse sociological methods available to them. We have to be realistic and accept the facts as they stand: sociologically speaking, we simply do not know or understand very much about the female in sport.

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Chafetz, J.S. 1974. *Masculine/Feminine or Human?* Itasca, IL: F.E. Peacock Publishers.

Dunning, E., ed. 1972. *Sport: Readings from a Sociological Perspective.* Toronto: University of Toronto Press.

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COMPATIBILITY, COHESIVENESS, AND SUCCESS AS RELATED TO WOMEN'S ATHLETIC TEAMS

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During the last decade, sociologists, psychologists, and educators have been absorbed in the study of the dynamics of group behavior. Whether the whole can be predicted from a knowledge of its parts is the empirical test of the ancient problems of "emergents"; therefore prediction of group outcomes from such knowledge is crucial. Thus, the composition of groups presents an ultimate challenge to any theory of human interaction (Schutz 1958). If the theory is valid, it must predict certain outcomes when particular people interact. The problem of group composition has important practical implications for composing such groups as therapy teams, army squads, research teams, committees, and teaching teams. The laboratory setting and the natural state in which athletic teams exist make them an ideal source for research regarding human interaction in small groups. Since compatibility and cohesion are considered critical determinants of group interaction (Melnick & Chemers 1974; Moos & Speisman 1962; Schachter et al. 1951), the level or degree of compatibility and cohesion between members of such small groups as athletic teams may be a contributory factor in the productivity or success of such groups.

For purposes of interpreting the literature reviewed in this report an operational definition of terms was deemed necessary. *Compatibility* exists when the roles given the *individual* group members are consonant with their preferred behaviors. Compatibility does not necessarily imply liking but the ability to have positive relationships in a group situation. *Cohesion* refers to feelings of belongingness, shared understanding of *group roles*, and teamwork.

Considerable research has shown that success in group tasks results in mutual attraction of group members. In an investigation designed primarily to study the effects of performance on certain aspects of leadership behavior, Farris and Lim (1969) examined the role-playing behavior of 200 management students. Their findings showed that members of a group having a high past performance record tend to be more compatible than members of a low past performance group. Peterson and Martens (1972) investigated the effect of success on the cohesiveness of 144 college intramural basketball teams. The results showed that team success increased postseason cohesiveness. Similar results were reported by Wilson and Miller (1961) in an investigation of 60 male students divided into two-man teams competing on a laboratory task. Winning team members rated their teammates significantly more positively after competition, while losing teams showed only a slight positive shift. Myers (1962) concluded that the competitive experience engendered good interpersonal team adjustment under conditions of success.

The literature concerning the effect of compatibility and cohesion on success tends to be much less consistent than that regarding the effect of success on group interaction. Although a number of investigators (Moos & Speisman 1962; Sapolsky 1965; Schutz 1958; Smelser 1958; Stotland 1957) have reported increased productivity as a result of initially compatible groups, Moos and Speisman (1962) observed that problem-solving performance was somewhat inhibited by the subjects' attempt to establish a good relationship. The majority of the investigations in this area used experimental designs consisting of two-person groups and interaction with strangers; therefore, the results may be of dubious value as related to athletic team interaction.

Another approach to the investigation of the structure and dynamics of group interaction in relation to productivity and success has been the measurement of group cohesion. The results of investigations concerning the effect of cohesion on success tend to be inconsistent. Fiedler and Meuwese (1963) reported that the more cohesive tank crews, bomber crews, and anti-aircraft crews performed significantly higher on various measures of performance appropriate to each crew. No significant relation was found between high cohesion and high productivity of 50 college females performing a cardboard cutting task (Schachter et al. 1951). However, the subjects were assigned to groups and instructed that the groups were either high or low in cohesion; no measurement of cohesion was utilized for group determination. Additionally, the subjects worked in isolation, communicating only through a complex experimenter-controlled note system. The investigators suggested that determination of the facilitative or inhibitive effects of cohesion on performance may be based on group success standards.

Although a majority of the research on cohesion, productivity, and success involves small groups working on laboratory tasks or in verbal interaction situations, a strong interest is developing in the investigation of those variables in regard to athletic teams. In a series of investigations, Fiedler (1954) studied the relationship of team effectiveness determined by the proportion of games won and emotional involvement of the team measured by a force-choice interpersonal perception variable questionnaire. The results of the initial exploratory study of the series, using 14 high school basketball teams tested at the beginning of the season, suggested that the members of the more effective teams tended to be emotionally less involved than did those of the less effective teams. Because of the small sample size and only moderately reliable scores, a validation study was subsequently initiated to test relationships found to be significant in the first study. Seven teams with a predominately winning season and five teams with a predominately losing season were measured near the end of the season. A correlation coefficient of −0.58 (p 0.03) was reported between the assumed similarity score and team effectiveness, suggesting that teams reflecting a lack of emotional involvement ended to be more task-oriented and more successful. The results of both investigations suggested that a high degree of cohesion interfered with effective performance.

Similar results were reported by McGrath (1962) in an investigation using 35 three-man rifle teams. Two types of teams were assembled based on interpersonal perceptual and behavioral indices: positive interpersonal relations teams and nonpositive interpersonal relations teams. The nonpositive interpersonal relations teams improved significantly in marksmanship and had significantly better marksmanship scores than did the positive interpersonal relations teams. McGrath suggested, as did Fiedler, that concern for the task more effectively promoted success than did concern for positive interpersonal relations with teammates. However, when investigators have instructed groups to attend equally to group maintenance and task performance, high productivity, high cohesion, and high satisfaction have resulted (Misumi & Seki 1971; Misumi & Sharakeski 1966).

In an effort to refute the long-held sociological theory that only low-conflict groups achieve high performance levels, Lenk (1969) studied the performance records and group integration of highly successful Olympic rowing teams, reporting an inverse relation between cohesiveness and group performance in that performance continued to improve despite vehement social intrateam conflict. Similarly Viet (1970) failed to indicate a positive relationship between aspects of cohesion and team performance effectiveness when studying 36 small-field ball teams, such as indoor handball teams consisting of 7 to 11 players, and of large-field ball teams, such as soccer teams consisting of 12 to 17 players. In an investigation of intramural basketball teams, Martens (1970) reported that high task-motivated teams were more successful and more satisfied than moderate or low task-motivated teams and that high affiliation-motivated teams were less successful but more satisfied than moderate or low affiliation-motivated teams. Klein and Christiansen (1969) collected sociometric data on seven members of a top-performing basketball team prior to their playing several three-against-three basketball games lasting three to five minutes. Triads were developed with every possible combination of three players. In contrast to aforementioned investigations, the results indicated a positive relation between cohesion and performance. Likewise, in a study of 144 intramural university basketball teams, measures of group cohesion were found to differentiate the successful and the unsuccssful teams significantly (Martens & Peterson 1971). In an attempt to replicate that study, Melnick and Chemers (1974) measured the relationship, cohesion, and win-loss records of 21 university intramural basketball teams. No significant relation was found between group success and group social structure. The investigators suggested that the lack of affirmation of a positive relation between the factors could have been caused by different standards of success, team tradition, and aspiration level.

The results of a recent study (Holland et al. 1974) of compatibility, cohesion, and success of women's athletic teams suggested that there were differences in compatibility among different teams. The nine all-female college teams were measured with the Firo-B at the beginning of the respective athletic season and with a Cohesion Scale and a Success Scale at the end of the season. Comparison of rankings suggested that compatibility and cohesion were not related to the success of the teams. Based on the results of rankings, the swim team was the most cohesive group but ranked low in compatibility. The field hockey team, which ranked low as a cohesive unit, had a high compatibility score. In contrast, the gymnastics team was high in compatibility and also ranked relatively high in cohesion. Developing compatibility within a team appeared not to be as essential as developing and working with individual personalities. Concerning the differences in members' assessment of success, the win-loss record seemed to have an effect on the team's view of their success. The swim team thought of themselves as the most successful. However, no relevant pattern emerged as the groups viewed themselves in regard to success. In conclusion, based on those teams and the instruments used, the team compatibility appeared not to be related to team cohesion or team success in any way.

There exists an obvious lack of agreement in the results of investigations of compatibility, cohesion, and success. In some investigations compatibility and cohesion were highly facilitative to group productivity or success, in others no substantial relation between the variables was found, and in still others the group dynamics variables seemed to have an inhibitory effect on performance. Landers (1974) suggested that the mutual independence of members of such groups as crew and bowling teams as opposed to the dependence of members of such groups as football and basketball teams may facilitate the development of intrateam competition, thereby inhibiting intrateam cohesion. The inconsistency of the results reported could have come from various methodological differences, such as the use of dyads and triads for group composition, artificially-induced group cohesion and compatibility, the use of intramural teams not having a clearly defined social structure, teams composed of members not strongly committed to winning, and divergent types of group interaction resulting from different task conditions.

Clearly, more research regarding the relation of group interaction factors and success in athletic competition is indicated. Relations among compatibility, cohesion, and success need to be investigated among participants in team sports, in dual sports, in individual sports, on male teams, on female teams, and on coed teams. There may also be differences between/among factors of compatibility, cohesion, and success for varying levels of play/sport, indicating needed investigation with specific regard to intramural, interscholastic, intercollegiate, and professional teams. In measuring the effect of compatibility/cohesion on success, success must be defined as team productivity related to win-loss records or to achievement of team goals.

In summary, the following conclusions may be drawn from these studies:

1. The greater the cohesiveness, the greater the power of the group to influence its members.

2. The desire of a group to establish good relations may slow down the problem-solving performance.
3. A group's level of communication and the tendency of its members to conform to the dominant group opinion on an issue may be related to the degree of cohesiveness within the group.
4. Groups composed of members with strong positive attitudes toward one another may be characterized by a generally high drive level.
5. Highly cohesive groups will produce more under a high-productivity norm. With a low-productivity norm, highly cohesive groups tend to inhibit productivity.
6. Group cohesiveness is much less a product of the members' relation to their leader than of the informal relations that arise spontaneously between individuals who are engaged in a common task.
7. Compatibility between members of small groups may be an important contributory factor in the productivity of such groups; therefore, the less compatible the relations, the more time must be spent in finding ways of dealing with difficulties. Thus, less energy is available to devote to the task.
8. Only when all members have high ability for their particular task is it possible for group performance to reach a maximal level.

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FEMININITY WITHIN SOCIAL ROLES AS PERCEIVED BY ATHLETES AND NONATHLETES*

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Femininity is a construct used to describe the constellation of social behaviors and attributes associated with the female sex role. As Mead (1949) points out, the word *femininity* reflects a culture's concept of acceptable or correct role behavior for its female members. In pre-technological societies, a somewhat singular conception has traditionally been used to describe the normatively prescribed behaviors within social roles. This view was perhaps adequate when such roles were highly definitive and numerically limited. Recently, however, we have witnessed an ever-increasing expansion of available social roles for women. Linked intimately with such expansion is confusion concerning the behaviors now considered feminine. Is it possible for a culture or society such as ours to maintain a perception of femininity in its traditional form? Or, as is more likely, will a society that finds itself in a period of change and transition modify its perceptions so that a construct such as femininity is redefined in a manner capable of absorbing and positively sanctioning previously prohibited or negatively sanctioned behavior?

Historically the arena of sport has been one from which women have been excluded to a great extent (Felshin 1974; Harris 1971; Hart 1972). Examination of the relevant literature (Brown 1965; Cheska 1970; Griffin 1972; Landers 1970) shows that female athletes were among the least highly evaluated and emulated and that they scored lower on femininity scales. However, with such recent developments as the federal government's implementation of Title IX and the increased media coverage of female athletes, there should be less discrepancy between the social role expectancies for the female and the presence of the competitive female in sport settings.

The female sex role and its related behaviors is viewed in the research literature from two general perspectives. The first postulates that femininity is the result of innate biological and physiological characteristics that influence subsequent sex role development (Garai & Scheinfeld 1968; Lindzey & Goldberg 1953). A fairly comprehensive summary and critique of this approach was completed by Maccoby and Jacklin (1974) and Holter (1970) from a cross-cultural perspective.

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* This study was completed in partial fulfillment of the requirements for McCullough's M.A. degree, under the supervision of Dr. Bird.

The second position — the one that forms the basis for this investigation — is generated from the literature on role theory and social learning. Roles are a set of prescriptions that define behaviors for persons as they relate to their status in society (Biddle & Thomas 1966). Roles are either ascribed or achieved. Ascribed roles are given to the individual regardless of innate talents or qualities and usually are based upon such easily differentiated and observable characteristics as gender, age, or race. Achieved roles, by contrast, are those the individual earns as a result of her unique talents and abilities, such as that of teacher, doctor, or athlete.

Social learning theorists such as Bandura (1962; 1969; Bandura & Walters 1963) emphasize that individuals learn social roles and their concommitant appropriate behavior through the processes of modeling (imitative behavior) and reinforcement. This view holds that role behavior is merely one form of learned behavior and is, therefore, subject to the same mechanisms for behavior modification and maintenance as all other learned behavior. Through the contingencies of reinforcement and modeling, the child is socialized into behavior patterns consistent with the cultural prescriptions associated with a particular social role, including the sex role (Rosenberg & Sutton-Smith 1960; 1972).

If, indeed, our society has changed its prescriptions regarding appropriate behavior within the female sex role, then as conceived from the social learning perspective, the two learning mechanisms of reinforcement and imitative behavior should both substantially affect subsequent female role enactment. Whiting (1960) and Flanders (1968) have both conducted investigations showing that children tend to select models based upon how many rewards the child sees the model receive. Bandura, Ross and Ross (1963) obtained empirical evidence demonstrating that children tend to choose models who are the giver of rewards. The results of these studies suggest, at least tentatively, that choice of a model is contingent upon two major factors: that the model is rewarded or reinforced or that the model is the source of power or reward. Recent changes within the realm of athletics appear to give some support to the premise that both types of models are now readily available to actual and potential female athletes. More precisely, women athletes and women's athletics in general are presently receiving increased media coverage; females are receiving and giving coveted rewards, such as athletic scholarships and professional tournament prize money.

If models and reinforcements do serve to modify behavior, and if sex role behavior is learned, then changes in the availability or functionality of models and in the criteria upon which reinforcements are contingent will in fact change that constellation of behaviors and attributes considered to be appropriate within any social role. Furthermore, if these changing conditions within the societal environment have in fact affected sex role perceptions, then the findings of this study should not exactly parallel those of earlier investigations.

This investigation focused upon two questions:

1. Is there a difference in perception of femininity by subjects classified as athletes as compared to those classified as nonathletes?

2. Do subjects regardless of athletic affiliation view femininity to be any different as exemplified within eight selected social roles?

METHODS AND PROCEDURES

Ninety female undergraduates between the ages of 17 and 23, enrolled at the University of Southern California, participated in the study. A semantic differential inventory was used to assess 45 athletes' and 45 nonathletes' perception of femininity as viewed within the following eight selected social roles: ideal woman, mother, housewife, hostess, sister, working woman, self, and athlete. Athletes were randomly selected from a master list of individuals who were members of at least one of the following intercollegiate athletic teams: basketball, fencing, gymnastics, swimming, tennis, track and field, and volleyball. Nonathletes were randomly selected from university housing lists and were not involved in any university-organized athletic program.

The semantic differential (Osgood, Suci & Tannenbaum 1967) has been used in similar research (Brown 1965; Griffin 1972; LeGrand 1976) and was selected as the best methodological approach based upon its reliability as a technique and its provision for within-role analysis through the dimensions of evaluation, potency, and activity. The evaluative dimension elicits qualitative judgements; activity typifies the dynamics of the role; and potency conveys power or role assertion.

Design consisted of three factors: two levels of factor one (groups), eight levels of factor two (social roles) and three levels of factor three (dimensions). The result was a 2 x 8 x 3 factorial design with repeated measures on factor two, social roles. Variance analysis was undertaken by means of a two-way Anova. The 0.05 level of significance was established for all analyses.

RESULTS

Table 1 presents the results of the variance analyses for the three factors of groups, social roles, and dimensions.

Table 1. Analysis of Variance: Groups x Roles x Factors

Source	df	MS	F
Groups (A)	1	322.79	2.19
Roles (B)	7	253.21	13.90*
Factors (C)	2	4990.43	94.80**
A x B	7	27.32	1.42
A x C	2	19.94	.38
B x C	14	246.22	14.48*
A x B x C	14	26.38	1.546

*p<.01
**p<.001

Results indicated no significant difference in perceptions of femininity based on group membership (athletes versus nonathletes). However, significant differences were found in role perceptions by subjects, F (7,616) = 13.20, $p < 0.01$. Tukey (hsd) post hoc analysis revealed the role of housewife to be significantly different from all other social roles, q = (8,712) = 2.55, $p < 0.01$; while the role of sister was different from all roles except self, q (8,712) = 2.55, $p < 0.01$. Femininity within the role of self was significantly different from that of ideal woman, q (8,712) = 2.29, $p < 0.05$, and housewife, q (8,712) = 3,807, $p < 0.01$.

Main effects for dimensions (evaluation, potency, and activity) were significant at the 0.001 level. Results of the Tukey (hsd) post hoc analysis showed that the evaluative factor was significantly different from both activity, q (3,267) = 6.25, $p < 0.01$, and potency, q (3,267) = 5.17, $p < 0.01$.

Further examination of the data revealed a significant interaction for roles by dimensions, F (14,1232) = 14.48, $p < 0.01$. Because of the multiplicity of significant F ratios, all the data were not presented schematically. Rather, the interactions of greatest relevance were presented descriptively. The role of ideal woman was the most highly evaluated; female athlete was the most potent; and mother was the highest on the activity factor. The role of housewife and mother were ranked below that of athlete on both evaluative and potency factors; housewife was least highly evaluated and seventh in potency.

DISCUSSION

Initial focus of the present investigation dealt with the question of variance in perception of femininity within eight social roles by subject classification as either athlete or nonathlete. Results indicated no significant difference between athletes' and nonathletes' perceptions. Viewed superficially, this finding appears somewhat contradictory to that of Berlin (1973), who found that female nonathletes saw an inverse relation between ideal woman and female athlete. Furthermore, she found no significant relation between the two social stereotypes as perceived by female athletes. In another somewhat similar study, Hall (1972) ascertained that a sample of English athletes and nonathletes did not identically perceive the concept of femininity within athletes. Her findings supported the presence of greater discrepancy between the feminine woman and the athletic woman within nonathletes as compared to athletes.

Adequate interpretation of these findings (Berlin 1973; Hall 1972) in relation to the present study necessitates consideration of at least two possible confounding variables. First, although Hall employed a methodological approach similar to that of this investigation — a semantic differential scale — the internal construction of the scales was not identical. Berlin's assessment instrument was the Activity Vector Analysis, which is an adjective checklist. Thus, as is common in social psychological research of this nature, the constructs measured — although uniformly labeled — were most likely not the same. A second factor is the geographical location of the samples employed. Hall's sample was located in England; Berlin's were tested in a geographical area of the United States quite different from that used in this study, Southern California. Both factors taken together lend support to the idea that the obtained results of these three studies, although appearing contradictory on the surface, may in fact be a result of (a) lack of agreement in the operation of relevant constructs and/or (b) geographical variability in perceptions of social roles.

This latter interpretation, in particular, may be explicated through a social learning perspective. In Southern California, the climate and topographical characteristics foster year-round and widespread sport participation by individuals regardless of gender. Secondary factors, such as typical dress, may also play a role. For instance, dress is casual, functional, and typically reflective of athletic participation. Although no conclusive evidence is available now, it may be defensible to assume that such circumstances affect the learning histories of individuals in diverse geographical areas and, therefore, their perceptions of behaviors and attributes deemed acceptable or desirable within selected social roles. Caution should be exercised when attempting to generalize the results of investigations designed to assess variables obviously affected by sociological conditions to unlike populations or settings.

The second question of relevance in this study was the possible presence of any differences among all subjects' perception of femininity within eight selected social roles. Subjects did perceive the eight roles differently. Results showed that the role of housewife was perceived as different from all other roles. The role of sister was also viewed as different. The latter finding could be somewhat attributable to a weakness in the design employed. Sister is a biologically-ascribed role and, therefore, not one with which all subjects would necessarily identify.

The finding that ideal woman was evaluated most highly by subjects is consistent with findings by Griffin (1972) and Jenkin and Vreogh (1969). It is of interest that the role of athlete was evaluated second only to that of ideal woman. It would appear that in considering all dimensions (activity, evaluation, potency) the female athlete is closest to ideal woman in demonstrating feminine characteristics — a finding contrary to that of other similar studies (Brown 1965; Griffin 1972). These results can be tentatively explained in terms of passage of time and concurrent societal changes or, as previously mentioned, variability attributable to the geographical location of the data collection. In California the outdoor, active female is a viable model for women, while intuitively the role of housewife appears to offer the least desirable role alternative to such a population. Further clarification can be made through the assessment of self in relation to the roles of ideal woman and housewife. Ideal woman was more highly perceived than self, whereas housewife was viewed more negatively than self. Therefore, it may be postulated that the role of ideal woman was seen as separate from self. Further, results showed that subjects apparently viewed the role of housewife as least similar to themselves.

Analysis of femininity by the interactive effect of role and dimension appeared to present a realistic and powerful assessment of roles by considering each role's capability of eliciting certain responses on each of the three dimensions. Osgood, Suci, and Tannenbaum (1967) suggest that the evaluative dimension should account for one half to three fourths of the variance between constructs measured. Results of this study showed the ideal woman to be most highly evaluated, with the female athlete receiving the second highest evaluation. This finding becomes rather important when one considers that the evaluative dimension is the one most capable of assessing attitudes. Therefore, findings would indicate highly favorable attitudes toward female athletes in general.

Some difficulty arises in attempting to explain why the role of mother was highest on the activity dimension. Apparently, the mother's activity was perceived as being more representative of feminine behavior within her role, while the activity of the athlete was ranked sixth. If this interpretation is valid, then the aspect of the female athlete's role viewed as least feminine is that of activity. Activity is considered to be the dynamics of the role enactment itself.

The findings of a high evaluative and low activity dimension within the role of female athlete provides some support for the speculation that the dilemma confronting the woman in athletics is one of within-role conflict. Viewed from this perspective, role conflict would occur as a result of a feeling that it is socially acceptable to be labeled an athlete, but the actual athletic activities and dynamics (i.e., aggression, physical contact, achievement) are unacceptable. Obviously, such a conflict would result in dissonance relative to societal normative expectations and real-life athletic participation.

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A CINEMATOGRAPHICAL ANALYSIS OF THE EFFECT OF VAULTING BOARD PADS ON TAKE-OFF VELOCITIES DURING VAULTING*

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Gymnastics is a sport that requires the development of the total body. Each of the Olympic events for men and women is designed to strengthen portions of the body and enhance each in relation to the whole. All of the events together develop the all-around athlete in gymnastics.

One of the events common to both men and women is vaulting. In this event, the area of the body that receives the most stress is the legs. The stress placed on the legs increases the probability of contracting shin splints, a hazard for both men and women vaulting competitors. This painful condition causes an interruption in the training program and puts the competitor at a disadvantage during the competition.

In an effort to eliminate or reduce the time lost in training because of shin splints, various methods — including warm-up exercises, several different taping techniques, tennis shoes, and padded runways — have been tried. One of the most recent of these has been the development of pads placed over the top surface of the vaulting board in an attempt to cushion the forces of impact. These pads were first used only in training, but as their use spread coaches started using them in competition.

The International Federation of Gymnastics for Men and Women officially adopted pads for use in competition. The women use a pad that can be no more than half an inch thick. The pad used by the men must be one inch thick.

The first concern among coaches as they began to use the pads was the reduction or elimination of shin splints; they gave little thought to the effect vaulting pads might have on the mechanics of the vault.

When a change is made in equipment, the intent is to improve the athlete's performance or safety. Changing the characteristics of the vaulting board by adding pads introduced an unknown variable to the most important part of the vault. The point of take-off is the deciding moment in determining the path of the center of gravity. The coach should be able to make a decision based upon research as to the possible effects of a pad upon a vaulter's performance.

The purpose of this investigation was to determine the effect of vaulting board pads on the take-off velocities of male and female high school vaulters. The null hypothesis to be tested statistically was that there would be no significant difference in the take-off velocities among the following three conditions: (a) vaulting board without a pad, (b) vaulting board with half-inch pad, (c) vaulting board with one-inch pad.

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*Condensed from thesis text.

REVIEW OF LITERATURE

Prior to this investigation, all research conducted on vaulting dealt with the use of unpadded vaulting boards. No research in such related areas as tumbling, floor exercise, or landing surfaces could be found dealing with the characteristics of the padding material used in the mats. The area of vaulting research applicable to the investigation included contact velocity, contact angle with the board, time on the board, angle of take-off, and take-off velocities. A summary of data from current research is found in Table I.

The literature shows that all subjects were highly skilled vaulters. The vaulters formed a homogeneous group in that they were similar with respect to both angles and velocities at contact and take-off. The similarity of this phase of vaulting for both male and female vaulters was evident even though several types of vaults were studied. Some variations in contact and take-off angles may be accounted for by the different methods of measurement. The speed at which the film was exposed has a direct relationship to the vaulter's contact time on the board and also to the approach and take-off velocities.

PILOT STUDY

Since no research has been found dealing with the characteristics of the material from which the pads are made, a pilot study was conducted to determine the rebound and absorption qualities of the two pads. It consisted of a drop test to determine the rebound qualities of the one-inch and half-inch vaulting pads.

An eight-pound, plastic coated, indoor shot put filled with lead was selected. The spherical shape proved best for obtaining vertical rebounds and accurate height measurements. Another reason for choosing the indoor shot was that it deformed uniformly upon contact, thus increasing the size of the contact area. This reaction approximated the human foot under high loads.

Table 2 summarizes the results of the drop test. A consistent rebound of two inches was recorded when the shot was dropped onto the cement floor from four different heights. The highest rebound was recorded when the shot was dropped onto the one-inch pad from a height of 20 feet. The one-inch pad consistently produced more than three times as much height in the rebound as did the half-inch pad. A maximum rebound of 46.2 inches was recorded for the one-inch pad and 15.2 inches for the half-inch pad.

The results of this study show that a greater amount of kinetic energy is returned to the shot put when the vaulting pads are used. Because the human body is not a perfectly elastic object, some of the rebound qualities of the pad might be lost through the musculature and joints. However, the

Table 1. Compilation of Kinematic and Kinetic Vaulting Data from Literature

SOURCE	N	Contact Speed (ft/sec)			Angles (degrees[a])		Duration of Contact (sec)	Take Off Speed (ft/sec)			Expected Force (lbs)	Frame Rate (frames/sec)
		Horizontal	Vertical	Resultant	Contact	Take Off		Horizontal	Vertical	Resultant		
FERRITER (women)	Best 4	17.9-21.7	-.33-.26	20.3[b]	75-84	97-115[c]	.07-.08	11.4-13.8	4.74-5.95	13.5	....	25
GOMBOS (men)	10	21.9	4.6	22.4	60	34	.07	16.3	11.1	19.7	1220.95	33
GUERRERA (men)	25	....	......	21.9	82± 5.7[d]	131± 5.3[d]	.12±.02[e]	......	......	18.9[e]	....	64[f]
KREIGHBAUM (pilot study men & women)	5	....	......	20.0-23.0	60-66	93-108	.08-.09	......	......	17.1-21.7	....	64
KREIGHBAUM (women)	8	....	......	20.12	64[g]	96	.114	......	......	22.61	2160	180+
POOL (women)	42	....	......	21.7[e]	....		.....	......	......	......	....	...
VANIS (men)	Best 4	19.3-24.0	4.2-5.5	22.4	64-73	92-99	.04-.09	16.2-23.6	13.2-13.9	24.0[b]	401.4-1224.8[i]	25

[a] Measured in degrees from left horizontal.
[b] Calculated by the writer from horizontal and vertical components.
[c] Measured by a line through the tragus of the ear to the lateral malleolus.
[d] Measured by a line from the center of support to the center of gravity.
[e] Significant correlation to score (P .05).
[f] Not standardization of the placement of the camera.
[g] Measured by a line from the metatatsophalangeal joint to the hip.
[h] Measured by a stop watch for the last 13 meters of the approach.
[i] Force reported in foot poinds but calculated as an impulse.

resiliency of the pad might increase the take-off velocity as it did to the shot put. In addition, the one-inch pad may have the most favorable effect upon take-off velocity.

Table 2. Rebound of Shot Put Dropped on a Padded and Unpadded Cement Surface from Different Heights

Height of Drop (ft)	Rebound Height (inches)		
	No. Pad	½ Inch Pad	1 Inch Pad
5	2	7.2	28.2
10	2	9.9	33.8
15	2	13.4	40.4
20	2	15.2	46.2

PROCEDURES OF THE INVESTIGATION

Three female and three male high school vaulters were selected as subjects. All subjects had to be able to perform the handspring vault and average at least an 8.0 score during the competitive season. Average or beginning vaulters were not considered in this study.

Cinematography

The vaults were filmed at 175 frames per second using a 16 mm LoCam camera with a telephoto lens. The camera was equipped with a timing device that exposed the edge of the film every tenth of a second. This was used to calculate the speed of the film and time the intervals between frames. Collection of data took place in the anterior-posterior plane of movement. White adhesive tape with a black locating mark was applied to several reference points on the right side of the subjects for use in film analysis.

Testing

First the women and then the men vaulted under each of the three conditions. Each subject in the filming used the same new Nissen vaulting board.[1] Warm-ups were allowed under all three test conditions: no pad, half-inch pad, one-inch pad. Each subject was then allowed two vaults in succession under each test condition. The approach was limited to a maximum of 20 meters for all subjects. The order of the test conditions was randomly chosen. Each vaulter was allowed another trial if the vault was determined to be unacceptable by the investigator. Each vault was judged to be acceptable if the vaulter was above 30 degrees of contact with the horse and the body was stretched when the feet left contact with the board.

Cinematographic Analysis

A qualitative descriptive analysis of the board phase of the vault was made using contourograms traced by the author from the film data of the

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[1] The research was supported by the Nissen Corporation and the Bio-mechanics laboratory at Washington State University.

36 vaults. The film data were also used to analyze the board deflections quantitatively during contact time. The contact and take-off velocities of the 36 vaults were quantitatively analyzed through the use of the computerized graphic tablet. The filmed image was projected upon an accoustically sensitized vertical glass tablet. A standard sparking pen was used to transmit accoustical impulses to the tablet, which was connected through a pen tablet control unit to an Interdata minature computer. The pen was touched to a reference point and sequentially to the following points: shoulder, hip, knee, ankle, and great toe for each frame. Data were collected for 10 frames before contact with the vaulting board to a point 10 frames after the feet had left the board. The data were stored on magnetic tape in the Interdata computer and then transferred to the IBM 360-67 computer by means of a computer program called IPUNCH. This program printed the raw data points on computer cards, allowing the data to be treated statistically using an analysis of variance program on the IMB 360-67 computer.

Statistical Treatment of Data

Analysis of the results of this study consisted of a qualitative descriptive comparison of contourograms of typical high school male and female vaulters and a quantitative analysis of the board deflection during contact time. For each condition (group, subgroup, and sex), means were computed for the angle of contact, time on the board, and take-off angle and compared for similarities and differences. An analysis of variance was computed for the contact and take-off velocities to determine any significant differences between the three test conditions.

RESULTS

The means of each condition, group, subgroup, and sex computed for the angle of contact, total time on the board, and take-off angle were compared for similarities and differences. An analysis of variance was computed for the contact and take-off velocities to determine any significant differences among the three test conditions.

Contourograms

Tracings of all vaults and a comparison of the resulting contourograms were made. All the subjects appeared similar in body position during all three conditions. The vault that came closest to the mean was selected for each sex as a typical example of a handspring vault. Figure 1 depicts the similarities of a typical male and female handspring vault. The contourogram shows that there is very little difference between the male and female vaulters. At the time of take-off and during the preflight, the positions of the vaulters' bodies are almost identical.

It appears that each vaulter is able to use the tenth of a second during which he or she is on the vaulting board to make adjustments in position in order to achieve the best common alignment for take-off. Kreighbaum (1973) suggests that vaulters may be approaching the limits of human ability to process necessary cues during the tenth of a second the body is in contact with the board and still have time for the musculature to effect a change in velocity or angle.

Film images and contourograms from other investigations (Ferriter 1964; Gombos 1962; Kreighbaum 1973; Vanis 1964) were measured and compared to the vaulters in the study. This comparison showed that the vaulters in the investigator's study were similar regardless of sex, type of vault, or whether the board was padded.

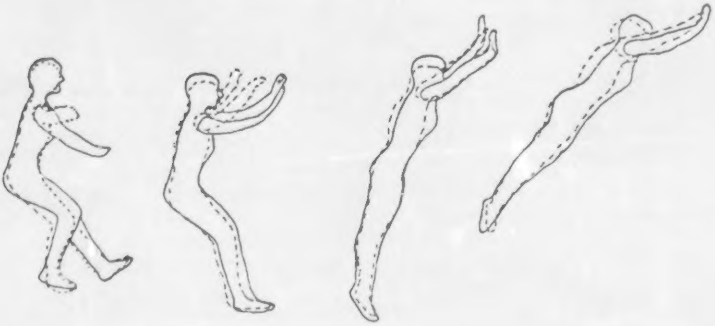

Figure 1. Countourogram showing approach, contact, take off, and preflight of a male and female handspring vault (- - - - male, ____ female).

Contact Angles

Mean contact angles for both men and women ranged from 60 to 61 degrees. There was less than a one-degree variation between the men and women vaulters for all three conditions. Women vaulters had the highest mean contact angle at 61.5 degrees while using the one-inch pad. The remaining conditions for women showed a mean of 60.5 degrees. The men varied only three tenths of a degree among all three conditions. Kreighbaum (1973) on women and Vanis (1964) on men both reported contact angles of 64 degrees.

Ferriter (1964) indicated a range of 75 to 84 degrees for contact angles when measured by a line from the tragus of the ear to the lateral malleolus. The author remeasured Ferriter's film data and contourograms using the method employed in this investigation. Using a line from the hip joint to the metatarsohpalangeal joint, Ferriter's six subjects indicated contact angles of 56, 60, 60, 60, 61, and 59 degrees, which agreed closely with the contact angles in this investigation. Based upon this and previous investigations (Ferriter 1964; Gombos 1962; Guerrera 1968; Kreighbaum 1973; Vanis 1964), it appears that 60 degrees is the optimum angle of contact and that vaulters achieve this angle regardless of whether the board is padded and whether the pad is one-half inch or one inch thick.

Contact Time

The mean contact time for both men and women subjects varied less than a hundreth of a second for all conditions. There were more shorter contacts by the men than the women. A qualitative film analysis of the board deflection relative to the time spent in contact with the board showed that all vaulters were able to produce a maximum deflection of the board from 0.022 to 0.028 seconds. Full deflection of the board was maintained for the next 0.222 to 0.034 seconds while the hip moved from behind the base of support to a position just in front. The remaining five hundredths of a second were used for leg extension to gain the vertical velocity necessary for preflight. Total contact times recorded in this investigation, which were filmed at 175 frames per second, agree closely with Guerrera (1968) and Kreighbaum (1973), who used camera speeds of 64 frames and 180 frames per second respectively. Investigations by Ferriter (1964) and Vanis (1964) were filmed at 25 frames per second. Subjects filmed at 25 frames per second recorded shorter contact times than those filmed at 64 frames per second or faster. Kreighbaum (1973) noted that film speeds of less than 64 frames per second cause some of the data to be lost between the frames, which accounts for the shorter contact times with slower film speeds.

Previous investigations used highly skilled performers. These performers all had contact times close to a tenth of a second. The research suggests that the optimum time to be in contact with the board is a tenth of a second. About five hundredths of a second of the total time is spent depressing the board and rotating the body forward for take-off. The remaining five hundredths of a second is used to accomplish hip, knee, and ankle extension. This short period of time may be reaching the limits of the vaulter's ability to perceive, analyze, and produce a correction in the take-off velocity or angle.

Take-Off Angles

The mean take-off angles did not differ more than 1.1 degrees. The men varied only four tenths of a degree for all three test conditions, whereas the women had a range of 2.2 degrees. The greater variation among the women was produced because subject one had a take-off angle of 93 degrees in the no-pad conditions. All take-off angles measured in the investigation agreed closely with those of other investigators (Ferriter 1964; Gombos 1962; Guerrera 1968; Kreighbaum 1973; Vanis 1964). The three different test conditions appeared to have no influence on the take-off angle. The author agrees with other investigators (Ferriter 1964; Gombos 1962; Guerrera 1968; Kreighbaum 1973; Vanis 1964) that the optimal angle for take-off appears to be between 95 and 100 degrees.

Approach Velocities

The mean approach velocity was 20.8 feet per second. There was a difference of 1.63 feet per second between the male and female vaulters with all conditions taken together. The velocities among the three conditions varied only 1.02 feet per second; the men's velocities were all higher than the women ($P<0.05$). An analysis of variance of the resultant contact velocities showed that the differences between the test conditions were not significant ($P<0.05$), although there was a significant difference ($P<0.05$) in the vertical contact velocity and no difference ($P<0.05$) in the horizontal velocity. Vaulters were apparently making no changes in the run-up and hurdle portion of the vault during the three testing conditions. The contact velocities in the investigation were consistent with those reported in other investigations (Ferriter 1964; Franklin & Trafton 1951; Guerrera 1968; Kreighbaum 1973; Vanis 1964).

Take-Off Velocities

Take-off velocities varied 1.69 feet per second between the male and female vaulters for all conditions. The variation among the three test conditions was 0.75 feet per second. The men showed higher ($P<0.05$) take-off velocities than the women as they did for contact velocities. The mean for men was 17.46 feet per second, and the mean for women was 15.73 feet per second. The highest velocities for men were recorded at 17.90 feet per second for vaults using the half-inch pad. The lowest take-off velocities, 15.51 feet per second, were recorded for the women while vaulting without a pad. There was no significant difference ($P>0.05$) in the three test conditions.

The mean take-off velocities of male and female vaulters in the present investigation were lower than those reported by other investigators (Franklin & Trafton 1951; Guerrera 1968; Kreighbaum 1973; Vanis 1964). Kreighbaum (1973) reported a mean velocity of 22.81 feet per second for women, and Vanis (1964) reported a mean velocity of 24 feet per second for men. Both of these studies used college competitors, while this investigation used high school vaulters. Differences in take-off velocities may be accounted for by the differences in the competitive experience and physical maturity between these two groups. Although the velocities were lower than those in other investigations (Franklin & Trafton 1951; Guerrera 1968; Kreighbaum 1973; Vanis 1964), they were consistent among all the subjects in this investigation.

It appears that a loss of acceleration of from three to five feet per second was occurring while vaulters in the investigation were in contact with the board. The subjects did not appear to be able to use the board as effectively as the vaulters in other investigations (Guerrera 1968; Vanis 1964). During the contact with the board, the vaulters were increasing their vertical component while the horizontal velocity decreased.

SUMMARY

A summary of the results of this investigation shows that the data from the subjects in the study were in close agreement with those of other investigations (Ferriter 1964; Franklin & Trafton 1951; Gombos 1962; Guerrera 1968; Kreighbaum 1973; Vanis 1964) other with respect to angles of contact, total contact time, contact and take-off velocities, and take-off angles. The vaulters in the investigation were at the optimum angles of contact and take-off according to several investigators (Gombos 1962; Guerrera 1968; Kreighbaum 1973; Vanis 1964). Analysis of variance indicated no significant difference among the three testing conditions except for the vertical contact velocity. The male vaulters had a significantly ($P < 0.05$) higher velocity than the female vaulters in all cases. The differences in the elastic qualities of the pads, which were noted in the pilot study, had no effect on the take-off velocities of the male and female vaulters. The present study did not determine why neither half-inch nor one-inch pads influenced the take-off velocities. However, we might speculate that (a) the gain in kinetic energy from the resiliancy of the pad is minimal when compared to the forces absorbed by the joints and musculature during contact with the board, and/or (b) the human body may be able to adjust subtlely to differences in surfaces with an alteration in the speed and force of the leg extension during the time spent on the board.

CONCLUSIONS

Within the limitations of the present study the following conclusions were drawn:

1. There appears to be no significant difference among the take-off velocities in the following three vaulting conditions: no pad, half-inch pad, one-inch pad.
2. The velocities of the male vaulters appear to be significantly higher than the velocities of the female vaulters.

IMPLICATIONS AND APPLICATIONS

A major implication of the investigation was that the difference in the thickness between the men's and women's pads could be eliminated in all phases of competition. One thickness of pad should be selected through an appropriate investigation, which would help the budgets of both men and women by eliminating the need to buy separate boards based solely upon the difference in pad thickness. There does not appear at this time to be any evidence to support one thickness of pad over another.

The investigation indicates a definite difference in the resiliency of the pad. It does not indicate the pad thickness that might effect the characteristics of the vaulting board. Coaches should investigate further with different thicknesses and materials. Three factors should be kept in mind when investigating the effects of different types of pads — body weight of the vaulter, leg strength, and speed of leg extension.

The original purpose of the pads was to cushion the shock of landing and thus reduce the potential for shin splints. The investigation did not deal with this problem directly. Since there appears to be no difference in take-off velocities between pads, coaches should experiment to determine the thickness of pad that will help reduce the probability of shin splints.

The film data in the investigation agree with previous studies in that vaulters appear to hurdle to the center of the visual field on the board. The optimum contact point on the board is at the highest point. During the approach, this point appears to be at the top edge of the field of view. The vaulter normally hurdles to the center of the visual field during the approach. This point is lower than the optimum and seems to be the natural position of contact. In order for the vaulter to raise the point of contact with the board naturally, a change in the top surface of the board may be necessary. A method that might be used during training is to place a wedged-shaped pad at the front of the board, which will raise the front of the board so that the vaulter can see it as the approach is made. The board will appear longer, and the visual center of the board will be moved up to the optimum contact point. The vaulter should be able to adjust naturally to the new center without undue effort.

Coaches and gymnasts should study the angles and velocities of the body during the time the body is in contact with the board, to help improve performance. It appears from the data that horizontal velocity and the speed of the leg extension are closely related. If a gymnast normally runs at 18 feet per second and increases the approach velocity to 24 feet per second, the center of gravity will pass over the board faster, necessitating an increase in the speed of the leg extension. Coaching the gymnast to run faster is not enough. The gymnast must also use proper training techniques to increase the speed and strength of the leg extensions. It must be kept in mind that more than half the time spent on the board is used in waiting for the body to rotate forward to a proper take-off angle.

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AN ELECTROMYOGRAPHIC STUDY OF THE RECTUS ABDOMINIS MUSCLE DURING SELECTED GYMNASTICS STUNTS

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As a former intercollegiate competitor and a gymnastics coach, this investigator frequently pondered the emphasis placed on the strengthening of abdominal musculature. Coaches stressed the importance of abdominal muscles in the performance of rolls on the balance beam, the glide kip on the uneven parallel bars, and such balancing stunts as the handstand.

Since the abdominal muscles do not cross the hip joint, their function must be primarily concerned with stabilization of the trunk and pelvis rather than the development of power for movement (Partridge & Walters 1959; Walters & Partridge 1957). The action of the rectus abdominis muscle is designated as flexion of the vertebral column, particularly the lumbar portion, drawing the sternum toward the pubis (Gray 1966; Rauch & Burke 1963). When the gymnast is performing a forward roll on the beam, this action may be achieved by gravity. In the back bend, handstand, and the skip, this action does not appear to occur. The question arises as to the importance of the abdominal muscles in certain gymnastic maneuvers.

It has been established that as a person becomes more proficient in an activity, extraneous muscular activity is eliminated (Fischer & Merhautova 1961; Manukovskaia 1959; Stepanov 1959; Zhukov & Zakhar'iants 1959). Fewer motor units are activated for a skilled performance of a stunt than for an unskilled performance. If one assumes the rectus abdominis contributes significantly to stabilization during certain stunts, the trained gymnast should exhibit some electrical activity in this muscle. The unskilled gymnast should display a greater amount of electrical activity than the skilled gymnast. If the rectus abdominis offers no significant contribution, the skilled performer should demonstrate no electrical activity.

This study was conducted to determine the function of the rectus abdominis muscle of trained women gymnasts during selected gymnastics activities. The findings of this study may suggest either that gymnastics coaches should revise their current emphasis on abdominal strength or that there is evidence to substantiate the practice.

REVIEW OF LITERATURE

The electromyographic technique has been employed as a testing procedure since approximately 1900, to determine the function of single muscles and muscles groups, to study the relation between muscle tension and action potential, and to compare muscle action potential in trained and untrained subjects. Much of this literature is noted in the bibliography.

Studies involving the abdominal musculature were particularly relevant to this study. Floyd and Silver (1950) used surface electromyography to compare the right and left sides of the abdominal musculature to determine their role in various activities. Head raising from a supine position produced marked activity in the rectus abdominis. In an erect position, extension of the trunk was controlled by the rectus abdominis and gravity served as the prime mover. The authors concluded that because all the abdominal muscles showed marked activity during leg raising, these muscles served as stabilizers of the pelvis.

Slater-Hammel (1943) examined the role of the upper and lower portions of the right and left rectus abdominis as a postural muscle acting during arm movements. It was found that during arm movements there were corresponding shoulder movements. The results showed that the rectus abdominis did not function in maintaining the balance of the shoulders over the pelvis. The right and left columns of the rectus abdominis did not necessarily function in a completely synchronous fashion, and there was considerable independence between the upper and lower portions of the muscle.

Walters and Partridge (1959; 1957) conducted two similar studies on the abdominal muscles during selected trunk movements of females. The amount of electrical activity of the upper and lower portions of the rectus abdominis was compared. The authors concluded that the sit-up became more difficult with the knees at a 65-degree angle, which relaxed the hip flexors. The sit-up and its modifications, trunk curl and variations, and the V-sit were rated as the most effective exercises. During isotonic contractions, the upper portion of the rectus abdominis participated more in activity involving the upper part of the body, and the lower portion of the muscle was active when the pelvis was tilted. When both portions of the muscle were acting as stabilizers, the segment farthest from the weight being lifted exhibited greater action potentials.

Parks (1959) collected electromyographic data on the anterior abdominal wall during selected exercises of trunk flexion and leg raising. He concluded that the lower portion of the rectus abdominis was most active in the greatest percentage of performers.

Flint (1965) studied the upper and lower rectus abdominis during selected exercises using electromyography and found a variation in response between the two portions of the muscle. It was concluded that most rectus abdominis activity during supine trunk flexion occurred during the first half of the movement and that trunk raising elicited more activity than trunk lowering.

Flint and Gudgell (1965) tested the external obliques and the rectus abdominis with electromyography in order to categorize various exercises in terms of abdominal strength. The less effective exercises — chin-ups, pull-ups, supine pelvic tilt, supine straight leg raising, vertical jumping, and isometric contractions — produced less action potential. Those exercises producing the greatest activity were the V-sit, side lying trunk lifts, backward leaning, and curl-ups.

Lipetz and Gutin (1968) compared the effects of four abdominal muscle exercises on the muscle action potential of the upper and lower portions of the rectus abdominis of eight trained male athletes. Sit-ups and modifications elicited greater activity than leg raising in both portions of the muscle; however, there was no significant difference in intensity among the sit-ups. The arched back sit-up caused both portions of the muscle to remain in a state of contraction for the greatest length of time at or above a moderate level of intensity. In all subjects, the action potentials were greater in the upper part of the rectus abdominis than in the lower part.

These authors (1969) conducted a similar study using 10 abdominal exercises. They found significant differences among the exercises in both the upper and lower rectus abdominis and ranked them in order of action potential as follows: basket hang, modified hook sit-up,conventional hook sit-up, hook sit-up with arm on chest, inclined and arched back sit-up, curl-up, conventional sit-up, V-sit, and backward lean. In some of the more strenuous exercise, many subjects produced greater action potential in the upper portion of the rectus abdominis than had been observed during a preliminary strength test. It was suggested that an inadequate amount of trunk flexion restricted the upper rectus abdominis from contributing fully to the strength measurement.

PROCEDURES

Bipolar electromyography in conjunction with videotaping provided data on the electrical activity of the upper, middle, and lower portions of the rectus abdominis muscle while six female subjects performed seven selected gymnastic stunts. The electromyograms, analyzed as a percentage of a maximum effort, were videotaped simultaneously with the performance of each stunt in order to permit both a visual analysis and a statistical analysis. All instrumentation was calibrated prior to use.

Clarke's cable tension strength test was used to determine the contractile power of the muscle (1966), enabling the investigator to quantify the data by examining the muscle action potential as a percentage of a maximum effort. Reliability was determined in a pilot study. A Spearman rank correlation was calculated yielding a perfect positive correlation (1963).

The gymnastic stunts represent the basic skills necessary for successful competition and were selected for three reasons. First, they purportedly require some degree of abdominal muscle activity, whether for stabilization or for additional power. Second, during the execution of these stunts the position of the vertebral column ranges from hyperextension to extreme flexion. Third, the stunts could be performed with direct electrode connections in contrast to the telemetry method, which requires more expensive equipment. The activities selected were as follows:

A. Tumbling and floor exercise
    1. Handstand
    2. Front limber
    3. Back limber
B. Balance beam
    1. Skip
    2. Forward roll

C. Uneven parallel bars
  1. Kip
  2. Single-leg shoot-through.

Both the stunt and the electromyogram were obtained on videotape, making it possible to determine when the rectus abdominis initiated, changed, and terminated its action during the stunts. In addition, the execution of each stunt was rated by two gymnastics coaches in order to allow for broader interpretation of the data.

All the electromyograms were sectioned equally. The amplitude value was multiplied by the number of spikes within the section to yield the amount of electrical activity. A nested one-way analysis of variance was used to test for differences among muscle portions, stunts, and stunts within muscle portions.

RESULTS

The mean percentages of each maximum muscle action potential score for each muscle portion are given in Table 1. Data from the analysis of

Table 1. Percentages of EMG Activity of the Three Portions of the Rectus Abdominis Muscle

Stunts	SB	SC	SL	CR	PP	CY
Handstand						
URA	43	34	13	44	52	19
MRA	57	42	15	76	49	20
LRA	63	47	15	. .	108	33
Down-phase limber						
URA	50	27	16	56	8	32
MRA	44	23	9	53	10	43
LRA	100	18	7	. .	0	37
Up-phase limber						
URA	81	107	26	261	101	71
MRA	136	88	17	179	55	83
LRA	133	136	19	. .	329	98
Down-phase back bend						
URA	19	21	9	0	25	30
MRA	14	17	7	4	19	35
LRA	58	37	2	. .	0	16
Up-phase back bend						
URA	. .	42	27	161	132	131
MRA	. .	34	27	99	116	94
LRA	. .	76	18	. .	346	164
Skip						
URA	24	35	24	22	8	8
MRA	31	16	22	30	18	15
LRA	81	41	9	. .	92	13
Forward roll						
URA	83	64	68	134	32	117
MRA	68	70	26	137	59	42
LRA	171	177	45	. .	141	54
Kip						
URA	118	90	111	155	86	87
MRA	74	79	66	109	50	50
LRA	182	161	63	. .	263	74
Single-leg shoot-through						
URA	119	87	81	194	100	54
MRA	76	82	56	93	38	40
LRA	204	228	83	. .	242	131

variance are given in Table 2. Since the purpose of this study was to determine the function of the three portions of the rectus abdominis during the selected stunts, the error term should have consisted of the interactions of SM, SE, and SEM. Because subjects were considered to be a random effect, the stunts mean square was tested using the interaction of SE, muscle portions using interaction SM, and interaction ME using interaction SEM (1963).

Table 2. Analysis of Variance

Source of Variation	df	SS	MS	F
Subjects (S)	5	224099	44819	
Stunts (E)	8	714538	89317	11.71
Muscles (M)	2	218957	109478	5.89
SE	40	304990	7624	
SM	10	185722	18572	
EM	16	114641	7165	2.48
SEM	68	194927	2881	
Within cells	373	351151	941	
Total	522	2300030		

Table 3. Weighted Mean Percentage of EMG Activity for the Three Portions of the Rectus Abdominis

Stunts	URA	MRA	LRA	AVG
Handstand	32	40	47	39
Down-phase limber	32	31	37	33
Up-phase limber	105	95	140	112
Down-phase back bend	18	16	24	19
Up-phase back bend	95	71	145	101
Skip	20	23	49	30
Forward roll	79	65	118	86
Kip	102	67	139	102
Single-leg shoot-through	97	61	169	107
Avg	64	52	96	

The F-test on the variation among muscle portion involvement revealed that significant differences were present at the 0.025 level. The two-way tables showed that the lower rectus abdominis exhibited an average of 96 percent of maximum activity, which is greater than either of the other two muscle portions (see Table 3). The percentage of the upper rectus abdominis was consistently greater than that of the middle portion.

The variation among stunts was significant at the 0.001 level. The kip, the single-leg shoot-through, and the up-phase of both the limber and the backbend elicited means of muscle action potential greater than 100 percent. The forward roll produced a mean of 86 percent. Lower mean percentages were calculated for the handstand, the skip, and the down-phase of both the limber and the backbend.

An F-test of the interaction EM was significant at the 0.01 level, indicating an interaction of stunt by muscle.

Descriptive analysis of the videotape revealed a similar pattern among subjects for each stunt except for the single-leg shoot-through. Graphic reproductions of typical electromyographic activity for three of the stunts are given in Figures 1, 2, and 3.

The electrical activity was constant throughout the handstand. This same pattern was present in the forward roll beginning from the point at which the neck touched the beam to the completion of the stunt.

The limber and backbend stunts contained a down-phase and an up-phase. The down-phases, ending with a hyperextended vertebral column, caused a low average percentage burst of activity in the rectus abdominis. The up-phases produced spurts of activity that were more than 100 percent of the maximum.

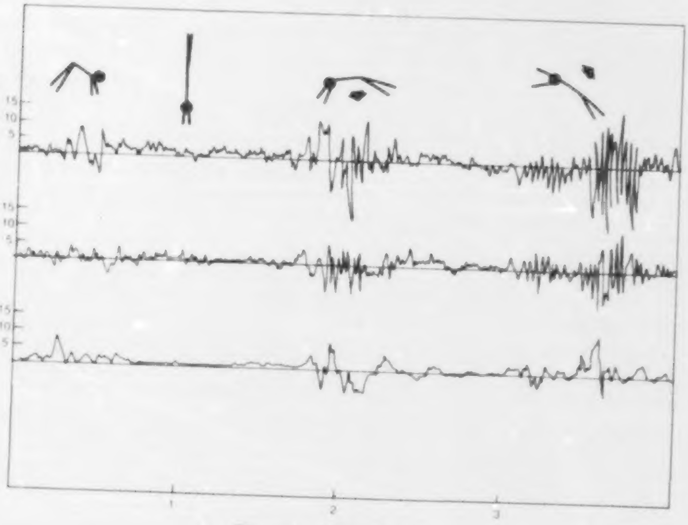

Figure 1. Representative pattern of muscle action potential for the front limber.

The skip on the balance beam caused activity in the rectus abdominis of two subjects during knee flexion. A third subject showed a steady amount of electrical activity throughout this stunt.

Two subjects showed activity throughout the kip, with very slight increases at the point of hip flexion. The slight increase in activity did not appear in the third subject.

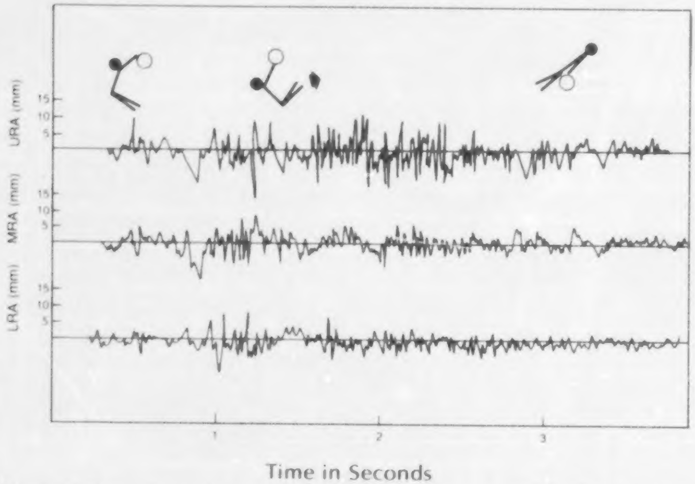

Figure 2. Representative pattern of muscle action potential for the kip.

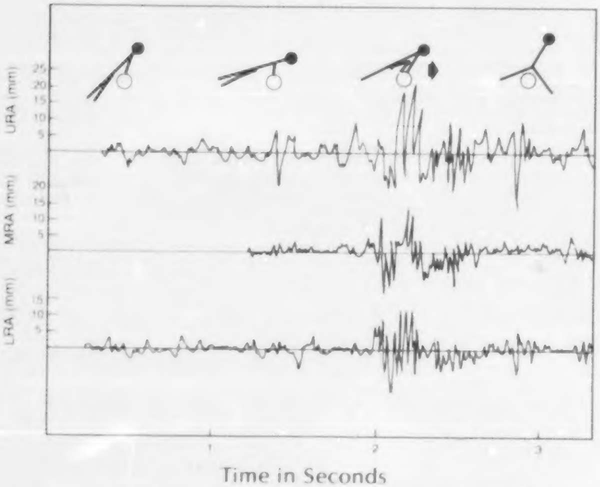

Figure 3. Representative pattern of muscle action potential for the single-leg shoot-through.

There was no set pattern of electrical activity produced by the single-leg shoot-through. One subject exhibited a steady amount of activity in the rectus abdominis, with artifacts occurring just prior to the leg-shoot. A second subject showed a similar pattern but, in addition, had a slight increase in activity at the leg-shoot phase. The third subject produced an increase in the steady amount of electrical activity after the leg reached the straddle position.

CONCLUSIONS

In this investigation the rectus abdominis functioned as a minor stabilizing muscle in the handstand, the lower portion having the greatest role. Since Walters and Partridge (1957) described the lower portion as a stabilizer during pelvic tilt, control of the pelvis may have been important in the successful execution of the handstand. Of the four subjects rated by the judges, the highest-rated subject exhibited the greatest muscular activity throughout the handstand.

The down-phase of the limber and the backbend produced only minor activity. These results are in agreement with Flint (1965), who showed that trunk raising required more abdominal activity than did lowering. Because gravity served as the prime mover, the rectus abdominis probably controlled this action by an eccentric contraction. The subjects who ranked first and second in performance maintained their ranks in percentage of activity. These two subjects also took one second longer to execute the stunt. The assumption may be made that they used less momentum to aid in the execution of the stunt because their movement was continuous. This may indicate that as skill level increases, more abdominal control is necessary.

The rectus abdominis muscle exhibited a greater magnitude of electrical activity in the up-phases of the limber and back-bend as indicated by the consistently high percentages. Lipetz and Gutin (1968) and Flint and Gudgell (1965) found that the backward lean and the arched back sit-up caused greater amounts of electrical activity than other sit-up modifications. This hyperextension of the vertebral column placed the rectus abdominis on stretch and apparently required more abdominal activity in order to maintain control and power. Perhaps gymnastics coaches should incorporate in their training programs abdominal strengthening exercises that place the rectus abdominis on stretch in order to achieve this control.

The skip on the beam required the rectus abdominis only in a minor capacity. Slater-Hammel (1943) found that the rectus abdominis did not assist in maintaining the shoulder alignment over the pelvis. However, the subjects ranked first and fourth in performance also ranked first and fourth in percentage of involvement of the rectus abdominis muscle. Therefore, this muscle may merely stabilize the pelvis during the time in which thigh flexion of one leg occurs.

The theory that the abdominal muscles function in the forward roll appears to be correct. The two subjects who tied for the highest rating exhibited very high percentages of muscle action potential. The rectus abdominis served as an important controlling agent throughout the forward roll.

In both the kip and the single-leg shoot-through the rectus abdominis was used at the 100 percent level or above. Its role in these stunts may have been one of power development, because flexion of the vertebral column occurred during these stunts. The rankings of the kip showed that the subject with the best performance used the rectus abdominis muscle to the greatest extent. On the shoot-through the subjects who ranked first and fourth maintained these ranks in percentage of muscle activity.

The conclusions, based upon the limitations of this study, were as follows:

1. The lower portion of the rectus abdominis muscle was more important than the upper and middle portions in the execution of these seven stunts.
2. The upper portion of the rectus abdominis exerted more influence upon the performance of the stunts than the middle rectus abdominis.
3. The rectus abdominis muscle performed a major function in the execution of the front limber, the backbend, the forward roll on the balance beam, and the kip and single-leg shoot-through on the uneven parallel bars.
4. Each stunt elicited a unique pattern of electrical activity.

It is recommended that gymnastics coaches identify abdominal exercises that simulate the stunt to be taught. It is also recommended that more coaches attempt to isolate further questions about the role of specific muscles in gymnastic stunts and develop studies to resolve the questions.

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RE-EVALUATION OF SWIMMING MOVEMENTS BASED UPON RESEARCH

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Although various refinements in swimming strokes have been evolving through the years, many of these improvements have emerged from trial and error or from attempts to duplicate movements made by leading competitive swimmers. The techniques of champions often have been copied blindly without due regard to the relative merits of the mechanical details of the performance. Consequently, the inefficient as well as the efficient components are imitated.

Descriptions of swimming movements are abundant in swimming literature available to coaches and teachers; however, the explanations rarely identify the hydrodynamic principles involved in the particular movements. Unfortunately, many descriptions are lacking in accuracy and are erroneous in terms of the identification of the forces responsible for body propulsion and resistance. As more controlled research of the variables involved in swimming is being conducted and reported, more accurate information may be given to the learner and competitor to expedite skill development, and efficient swimming techniques can emerge as the result of applying this knowledge.

It is hoped that this presentation will serve to promote an understanding of the forces acting on the swimmer that help determine the resultant motion of the body through the water. With the recognition and understanding of some basic principles of fluid mechanics, the teacher will be in a better position to analyze any given stroke technique and prescribe modifications necessary for improving the effectiveness of the performance.

GENERAL CONSIDERATIONS

A body's state of motion, whether it is still, increasing or decreasing in speed, or traveling at a uniform velocity, is dependent upon the forces acting on that body. Identifying the forces that influence the motion of a body through water is a somewhat more difficult process than identifying the forces acting on a body in land activities. In the latter, external forces affecting body motion are more easily visualized and measured than are the forces created by the "invisible" medium of water, which a swimmer uses for propulsion and which serves also to retard the swimmer's progress.

Two categories of force are of interest with respect to a swimmer's performance: (a) forces produced by the swimmer's movements used for forward propulsion of the body and (b) forces that retard the swimmer's forward progress. Both propulsive and resistive (retarding) forces depend upon similar factors, and it is a matter of one's taking advantage of some characteristics of fluid behavior to maximize the forces that can be developed for propulsion while minimizing the forces that retard the swimmer. Consideration of both types of force is necessary for understanding the resulting motion of the swimmer's body.

Several basic principles might well serve as a foundation. Consider a propulsive force created by a swimmer's limb movements through the water. The body will respond with an acceleration forward if the retarding forces against the body are kept low. Acceleration will occur only as long as the propulsive force is applied in excess of the oppositely directed resistive forces. That is, the body acceleration will vary as the difference between propulsive and resistive forces. Constant body velocity is achieved when the propulsive forces are equal in magnitude to the oppositely directed resistive forces, i.e., when the body is in a state of dynamic equilibrium. As the body accelerates, however, it gains velocity, and the resistive forces increase dramatically until they become equal to the existing propulsive forces. At that time no further acceleration occurs and, as soon as it becomes anatomically impossible for the swimmer to continue applying the same amount of force to counter the resistance, the body decelerates. It is recognized that periods of body acceleration and deceleration in swimming demand a greater energy expenditure than does the maintenance of a relatively constant body velocity.

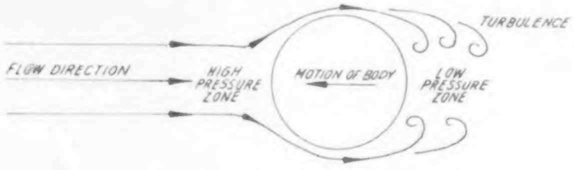
FACTORS CAUSING RESISTANCE TO FORWARD MOTION OF THE BODY

There are three fundamental types of fluid forces that act to retard the swimmer's forward progress: (a) surface drag, or skin friction; (b) wave drag; and (c) profile (form), or pressure drag.

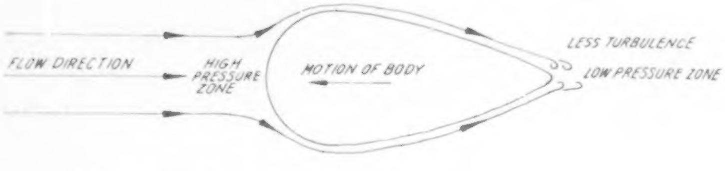
Surface drag, or skin friction, is a retarding force caused by the water flowing backward along those surfaces of the body that move forward through the water. Compared to the other types of resistance, it is probably of least significance. The smoother the skin and swimming suit, and the smaller the surface area of the body, the smaller this source of resistance. Changes in competitive swimsuit materials have been based on the desirability to reduce this skin friction, as is the practice of shaving the body and legs if the amount of hair is excessive. Whether the arms should be shaved to decrease friction is open to question, since the direction of the frictional force on the arms during their underwater movements would tend not to resist forward body motion but might actually contribute to the propulsive effort. This factor will become more apparent in the discussion of propulsive forces.

Another source of resistance is wave drag, or the formation of waves at the water's surface in front of the swimmer. As the speed of the swimmer increases, the size of these bow waves increases and the "wall" of water presses backward against the swimmer, just as the wave against a bridge piling exerts more force as the speed of flow increases in a river. Bow waves will be formed against the leading surface of any parts of the body moving through the air-water interface. The formation of bow waves also will increase with up and down movements of the body as well as with swimming speed. When the swimmer is completely submerged, wave drag is eliminated.

The viscous pressure drag — often referred to as profile, or form, drag — is a significant form of resistance in swimming. The amount of profile drag depends on the size, shape, and speed of the swimmer. As the body moves forward through still water, the water flows backward relative to the body. The water is "spread apart" to allow the body to pass through it, and the greater the area of the body and body parts that face the flow of water, the greater is the drag. High-pressure zones are created on the leading surfaces of the body, and low-pressure zones are formed at the trailing surfaces where the water is turbulent, thus creating a suction effect. The result is a net force backward against the swimmer (Figure 1). As the speed of flow past the body increases, the pressure differential increases and the resistance becomes dramatically larger. As the area of the body facing the flow is decreased, as when maintaining a horizontal body position rather than one in which the legs are lower than the upper



a) NON - STREAMLINED BODY (GREATER PROFILE DRAG)



b) STREAMLINED BODY (LESS PROFILE DRAG)

FIGURE 1. PROFILE DRAG CREATED BY A PRESSURE DIFFERENTIAL BETWEEN THE FRONT AND BACK SIDES OF A BODY MOVING THROUGH WATER. THE DRAG FORCE ACTS IN THE SAME DIRECTION OF FLOW PAST THE BODY.

body, the profile drag can be effectively reduced. If the body shape is streamlined — that is, if the body tapers gradually from shoulders to hips to feet — the profile drag will be less than it would be for a body with irregular contours. Contours in the body cause water to flow at varying speeds around these shapes, and turbulence is created on the downstream side, thus producing low-pressure (suction) zones. The streamlined shape is largely predetermined by the swimmer's body build, whereas the body position in the water is a factor that can be controlled in the stroke performance.

The sum of the three types of drag is normally referred to as "body drag," the resistive force that must be overcome by the propulsive forces if the swimmer is to increase speed or one that must be matched by the propulsive forces if the swimmer is to maintain a constant speed. A swimmer's speed may be considered fairly uniform over a given distance, such as 25 yards or a quarter mile, but it has been shown that within a single stroke cycle the body velocity varies from moment to moment (Barthels 1974). As the resistive forces become greater than the propulsive forces, the body decelerates, as in the elementary backstroke during the underwater recovery movements of the arms and legs. During this phase the arms and legs present a greater surface area to the flow, and the velocity of the flow past the forward-moving limb is even greater than the flow velocity past the body. In order to keep the resistive drag on the limbs to a minimum, the speed of the underwater recovery movements should be relatively slow, and the surface area of the limbs facing the flow should be kept to a minimum. A more constant body velocity is observed in the front crawl stroke, for example, because the limbs operate to provide some propulsive force throughout the total stroke cycle.

FORCES INVOLVED IN FORWARD PROPULSION OF THE BODY

Most descriptions of swimming define limb movements relative to the swimmer's body, because this is what is most apparent to the observer and to the swimmer. However, the motion of the limbs must be examined relative to the still water through which they are moving; that is, relative to the medium that provides the counterforces necessary for propulsion of the body. In order to identify the forces acting on the limbs as a result of their movements, it is necessary to focus on the nature of the flow of water past the moving limb, for it is this flow relative to the moving part that is responsible for the forces that result.

Forces Generated by the Arm and Hand

Two types of force can be produced by a swimmer's arm and hand moving through the water. One is drag force, discussed under resistive forces as profile drag. Drag force results from a paddling or pushing movement through the water and acts against the direction of hand motion through the water. The other type is lift force, created by slicing or blading movements of the hand, as in sculling. Lift force acts on the hand in a direction perpendicular to the flow past the blading hand. It is important to realize that the direction of a lift force is *not* necessarily upward, as the term implies.

Figure 2 shows how a drag force is produced on the hand if it pushes backward through the water so that the force is directed against the palm. A high-pressure zone is creatd on the palm, and a low-pressure zone is created on the back side of the hand. Figure 3 shows how a lift force is produced on the hand when it blades through the water so that the flow encounters the palm at a small angle. The lift force is directed perpendicularly to the flow direction past the hand. This is the type of force created on the hands as they are sliced inward and outward by a person treading water in an upright position. When the hand is sliced outward away from the long axis of the body, the hand is turned so that the palm again encounters the flow at a small angle of attack. The hands do not push downward toward the feet, but remain blading inward and outward in the same horizontal plane underwater. Used in this manner, the hands create what might be called "lift force handles," which provide the counterforce on the hands necessary for maintaining the head above the surface of the water. Figure 3 also may be interpreted as a bottom view of a person, in a horizontal position in the water, who is slicing the hand inward and

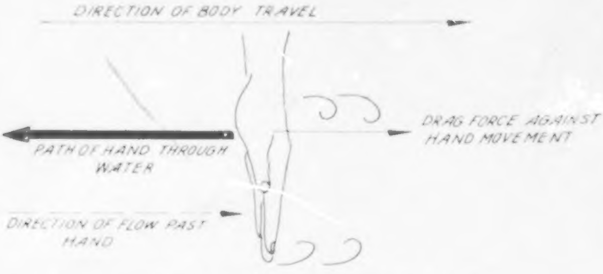

DIRECTION OF BODY TRAVEL
DRAG FORCE AGAINST HAND MOVEMENT
PATH OF HAND THROUGH WATER
DIRECTION OF FLOW PAST HAND

FIGURE 2 DRAG FORCE ON HAND WHICH IS ORIENTED PERPENDICULARLY TO FLOW DIRECTION

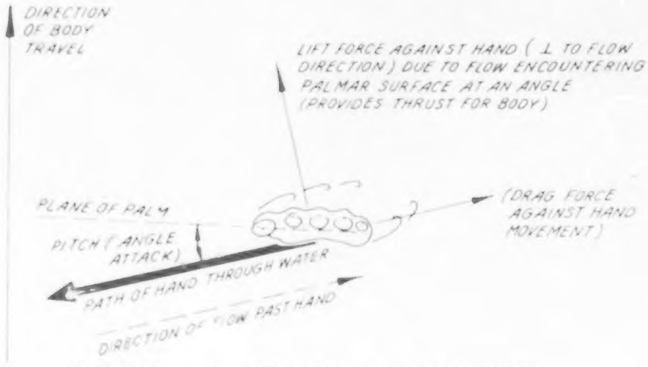

DIRECTION OF BODY TRAVEL
LIFT FORCE AGAINST HAND (⊥ TO FLOW DIRECTION) DUE TO FLOW ENCOUNTERING PALMAR SURFACE AT AN ANGLE (PROVIDES THRUST FOR BODY)
PLANE OF PALM
PITCH (ANGLE ATTACK)
PATH OF HAND THROUGH WATER
DIRECTION OF FLOW PAST HAND
(DRAG FORCE AGAINST HAND MOVEMENT)

FIGURE 3 LIFT FORCE ON HAND WHICH IS ORIENTED OBLIQUELY TO FLOW DIRECTION.

outward (large sculling movements) to create a counterforce against the hand for producing forward motion of the body.

Lift force can be explained in terms of Bernoulli's Principle, which states that in a region of high flow velocity, a low-pressure zone is created; and in a region of low flow velocity, a high-pressure zone results. For example, when air [illegible] past an airplane wing, the flow velocity above the wing is high and a [illegible]ssure region develops. Under the wing the flow velocity is low, and a high-pressure zone develops. As a result, there is a net force on the wing directed from the high-pressure zone to the low-pressure zone. This same type of pressure differential is created on the hand when it blades through the water with a small angle of attack between the palm and direction of flow past it.

In both drag force and lift force, a pressure differential is formed between the palmar and dorsal surfaces of the hand, and how the hand is moved through the water determines the nature of the resulting forces that may be used as counterforces for forward propulsion of the body. If the hand's backward push through the water (drag force) or lateral slicing of the hand through the water (lift force) can produce forces on the hand to be used for moving the body, what kind of hand movement would be more effective in swimming?

Consider the following rationale describing how each type of hand motion could be used to produce forward body motion. The purpose of underwater hand motion is to produce a counterforce on the hand which, ideally, would prevent the hand from moving backward through the water when the shoulder muscles contract. Contraction of these muscles would then cause the body to be moved forward past the hand until the range of arm motion is completed. At that time the hand must be placed into a new position in the water ahead of the body so that the body may again be moved forward through the water. The popular notion is that in order to move the body directly forward the swimmer must pull or push directly backward through the water with the hands. This viewpoint has been based on the assumption that a drag force on the hand is necessary for propulsion. Such a drag force could provide an adequate counterforce on the hand against which the swimmer may pull or push the body forward if the backward speed of the hand and arm were great enough. The greater the surface area of the hand facing backward and/or the greater the backward hand velocity through the water, the greater will be the drag force resistance on the hand for moving the body. The use of hand paddles increases the surface area of the hand so that hand motion backward creates the necessary drag counterforce to propel the body; however, when the paddles are removed the hand must move backward much faster to obtain the same resistance. The faster the hand moves backward through the still water, however, the sooner the arm reaches the end of its range of movement. Consequently, the body itself will have traveled a shorter distance per arm stroke than it would have if the hand had not moved back through the water but had remained in the vertical plane of water past which the body was to be moved.

Moving the hand back through the water in this manner to create drag force on the hand for moving the body is comparable to performing a pull-up on a bar that moves downward as the body is pulled upward: the body moves only a short distance relative to the ground. Using the hand to create lift force on the hand — that is, by blading it laterally in a transverse plane so it does not move backward as much through the water — is comparable to performing a pull-up on a stationary bar: the body can be moved a greater distance relative to the ground in one arm "stroke." Thus, by moving the hand more in a direction transverse to body travel, the horizontal lift force on the hand could provide a more stable "handle," or firmer counterforce, and the body could be moved over a greater distance by the contraction of the shoulder muscles. Simultaneous front and side view films of skilled butterfly swimmers show that the hands do not, in fact, move directly backward through still water, although that is the impression the swimmer has. It has been established (Barthels 1974) that the hand moves in a three-dimensional path (helical), so that throughout the underwater portion of the stroke the flow of water is encountering the palm at a small angle of attack and the leading edge of the hand is constantly changing with respect to the flow passing it. This continuous, multidirectional blading hand movement leads to the generation of lift forces on the hand, which inhibit rapid backward hand and arm movement relative to the water when the shoulder muscles contract. Such blading movements, therefore, create a firmer handle for moving the body forward.

The film tracing in Figure 4a illustrates the nature of the underwater hand movements of a skilled butterfly swimmer as viewed from the front.

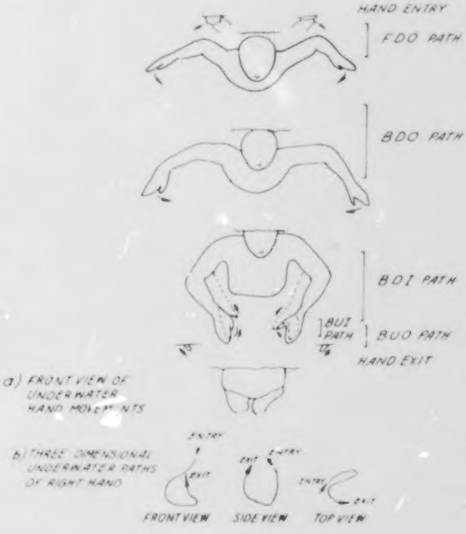

HAND ENTRY
FDO PATH
BDO PATH
BDI PATH
BUI PATH
BUO PATH
HAND EXIT
a) FRONT VIEW OF UNDERWATER HAND MOVEMENTS
b) THREE DIMENSIONAL UNDERWATER PATHS OF RIGHT HAND
ENTRY
EXIT
ENTRY
EXIT
ENTRY
EXIT
FRONT VIEW
SIDE VIEW
TOP VIEW

FIGURE 4 THREE DIMENSIONAL UNDERWATER HAND MOVEMENTS OF A SKILLED BUTTERFLY SWIMMER.

This tracing shows the orientation of the hands as they are moved in identifiable three-dimensional paths. In Figure 4b the actual path of the right hand relative to still water is shown for a front view, side view, and top view of the motion. From the swimmer's point of view, and from the point of view of the casual observer, the hand seems to be pressing backward through the water as the stroke is performed; however, the body is actually being pressed forward past the hand as it is blading through the helical path. Studies of strokes other than the butterfly have revealed similar three-dimensional patterns of hand motion used for propulsion (Counsilman 1970).

The speed of the blading hand is important for generating lift force, and this hand speed is produced when the swimmer flexes the elbow to move the hand in a transverse plane. Since maximum hand speed occurs during mid-range of the arm's angular movement, the greatest lift force is produced during that phase, while the least amount of lift force is produced at the beginning and end of elbow flexion. It is at these points in a stroke that the hand and arm exhibits the most backward movement relative to still water (Barthels 1974). These points coincide with the points at which the hand must change direction for the next blading movement. These small backward hand movements create some drag force on the limb, which contributes to the total counterforce necessary for propelling in the body. In order to take advantage of the large lift force on the hand during the transverse blading movements, these midstroke "sculls" must be coupled with the forceful contraction of the shoulder muscles which pull the body forward past the hand. Anatomically, the opportunity for performing these two actions occurs when the upper arm moves through the middle part of its range of motion at the shoulder. At this time most of the lift force on the hand is in the direction of desired forward body motion. Moreover, it is during this phase of the arm stroke that the swimmer's body exhibits the greatest forward response to the arm movement; that is, there is more forward body motion when there is the least backward hand motion relative to the water. This response is observed in the front crawl and butterfly when the elbow is flexing and extending under the body, in the back crawl when the elbow is flexing in a transverse plane next to the body at shoulder level, and in the breast stroke when the hands blade outward and then inward under the shoulders. It is seen also in the leading arm of the sidestroke as the elbow is flexing to move the hand in a transverse plane under the head and shoulder. In the elementary backstroke the blading of the hands in the body's transverse plane is limited, because both upper arms cannot be submerged deeply enough to allow much elbow flexion without bringing the hands out of the water. In the elementary backstroke, the drag force on the hands and arms during the initial phase of shoulder adduction provides some useful counterforce; however, as the shoulder adduction continues, the direction of water flow relative to the hands and arms changes. The nature of the forces acting on the hands and arms then becomes similar to that observed past the legs in a flutter or dolphin kick.

Forces Generated by the Legs

The thrust developed by the legs in the various styles of kicking has generally been attributed to drag force. This assumption is the result of examining the movements of the legs relative to the body of the swimmer rather than to the water through which they are moving. In order for drag force to be exerted on the legs for forward thrust, the legs must move backward relative to still water so that the water flows past them in a forward direction. This condition occurs to some extent in the whip and scissors styles of kicking, at the beginning of leg extension when the body speed is relatively slow. Subsequently, however, as the body moves forward, the legs are pulled forward with the body and experience a backward flow of water from that motion. At the same time, the legs are moving in a transverse direction and a transversely directed flow occurs as a result of that motion. The result of these two directional flows occurring simultaneously is that the actual flow is directed past the leading surface of the leg at a small angle of attack in more of a backward direction. Figure 5 illustrates the nature of the flow during the performance of a flutter or dolphin kick. As the flow encounters the leg at a small angle of attack, a lift force is generated in a direction perpendicular to the flow (Figure 6). The forward component of this lift force is the thrust useful for forward body propulsion. This is the same type of flow condition created on the caudal fin of a dolphin or whale when the tail undulates in a transverse plane as its body moves forward.

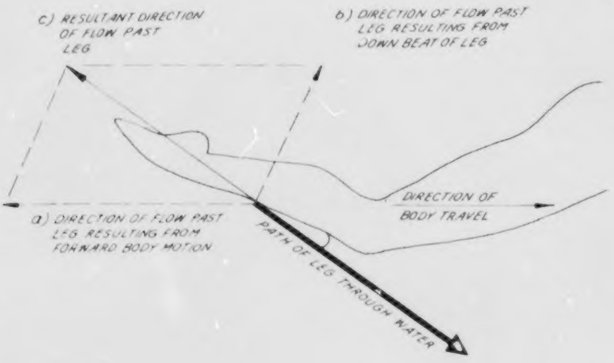

c) RESULTANT DIRECTION OF FLOW PAST LEG
b) DIRECTION OF FLOW PAST LEG RESULTING FROM DOWN BEAT OF LEG
a) DIRECTION OF FLOW PAST LEG RESULTING FROM FORWARD BODY MOTION
DIRECTION OF BODY TRAVEL
PATH OF LEG THROUGH WATER

FIGURE 5. RESULTANT FLOW DIRECTION PAST THE LEG IN A FLUTTER OR DOLPHIN KICK DURING THE DOWN BEAT OF A MOVING SWIMMER.

Flow conditions similar to those in the flutter kick can be seen during the final phases of the underwater arm stroke in the elementary backstroke, front crawl, back crawl, butterfly, and for the trailing arm in the sidestroke.

In the whip kick the flow relative to the soles of the feet is similar to that created on a propeller blade as it moves through a helical path in the

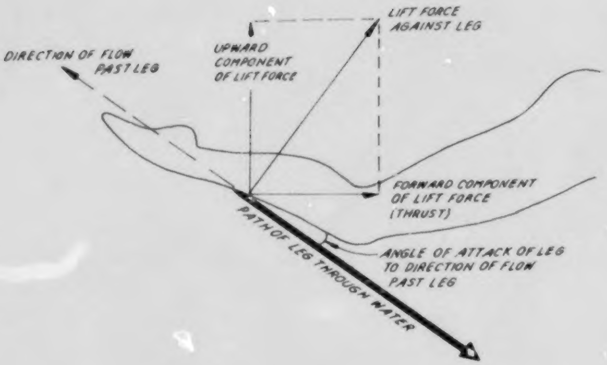

LIFT FORCE AGAINST LEG
DIRECTION OF FLOW PAST LEG
UPWARD COMPONENT OF LIFT FORCE
FORWARD COMPONENT OF LIFT FORCE (THRUST)
ANGLE OF ATTACK OF LEG TO DIRECTION OF FLOW PAST LEG
PATH OF LEG THROUGH WATER

FIGURE 6 LIFT FORCE RESULTING FROM A FLUTTER OR DOLPHIN KICK DURING THE DOWN BEAT OF A MOVING SWIMMER.

water. As the feet blade through the water in spiral-like paths, the lift force generated on the feet provides a fairly stable counterforce against which the legs may extend and thrust the body forward.

SUMMARY AND IMPLICATIONS

It is clear that the examination and evaluation of any swimming skill is no simple task. The initial evaluation of a specific stroke is usually accomplished by comparing it with some model of efficient performance. Successful competitors serve well as such models; however, the details of individual styles should not be copied without a sound mechanical rationale for doing so. A valid stroke analysis demands an understanding of the forces created by the body parts interacting with the water in addition to a knowledge of the anatomical capabilities of the swimmer. In order to recognize the forces affecting the swimmer's progress, attention must be focused on how each body part moves relative to the water surrounding it. Traditionally, propulsive movements of the limbs are described relative to the swimmer's body rather than to the resistive medium. If limb movements are not analyzed relative to the still water, important aspects of force production often go unrecognized. The blading movements of the hands in a transverse plane should not be considered symptomatic of muscular weakness. Such movements are made to secure a stable water handle, which the swimmer can use to press the body forward with each arm stroke. If it is kept in mind that the body should be moved forward relative to the hands, instead of the hands moving backward past the body, the importance of the blading handles is evident.

If the propulsive movements of the arms and legs are to result in appreciable forward body motion, the total body drag must be minimized. In order to accomplish this, attention should be given to reducing, where possible, the three contributing types of drag.

Much work is yet to be done in aquatic research in order to identify further the variables affecting the efficiency of human swimming. If the results of such research continue to be recognized and applied by teachers and coaches, much of the trial and error may be removed from the learning process.

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AN INFORMATION SURVEY OF WOMEN COMPETING IN THE 1975 AIAW NATIONAL SWIMMING CHAMPIONSHIPS

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The past few years have witnessed many changes with respect to women, including some significant changes in women's athletics. Among them is the encouraging attitude toward support of college-level competition for women's sports, evidenced by the increase in the availability of both athletic competition for college-age women and financial support for outstanding and/or needy athletes.

Specifically, 1974-75 was the first year in which women eligible to compete at the college level in athletics received significant amounts of financial support in the form of athletic scholarships and/or grants. It seemed appropriate, therefore, to investigate the status of women college athletes with respect to competition and financial aid. The 1975 AIAW National Swimming Championships, held at Arizona State University in Tempe, March 13 to 15, 1975, provided an opportunity to secure current information on this topic with one of the recognized AIAW sports.

The investigation took the form of a survey designed to gather information that might shed some light on the present situation of women in college competition. The results should be of interest and value to those working to promote girls' and women's competitive sports.

Quite frankly, it was not known what to expect from a survey of women swimmers at the national championships. How many would be on scholarship? How many would have quit swimming competitively if college-level competition had not been available? Were they getting fair use of pool facilities? These were the types of questions for which answers were sought in the survey.

PROCEDURES

There were three phases to the investigation: (a) development of a questionnaire, (b) selection of a sample to be surveyed, and (c) the collection of data. Permission to conduct the study was first sought from the Association for Intercollegiate Athletics for Women (AIAW). A proposal was sent to the NAGWS Research Committee, and their permission and support was granted for the study.

Included in the proposal was a sample of the survey form to be used. In their letter of approval were suggestions for items that might be added and changes that might make the questionnaire more precise. These were

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incorporated, and the final form was circulated among various people with experience in either women's sports or survey work for any final suggestions for improvement. The questionnaire's final format was influenced by two considerations: (a) the survey form had to be no longer than one page (the final form fit on one side of a legal-size page); and (b) the responses had to be as simple as possible in order to facilitate data gathering among the athletes at the meet.

Because the swimming meet was larger than in the previous two years by more than half (itself an indication of stronger support of women's athletics by schools), it was determined that a random sample would be taken to secure the information. A confidence level of 95 percent with a permissible error figure of ±5 percent was chosen on which to base the significance of the results.

A total of 572 swimmers were actually pre-entered in the meet (exclusive of divers, who were not included in the survey because of the location of the diving competition). A sample number based on the confidence and accuracy levels chosen was determined to be 229*, and because of "no-shows" at the meet the final survey sample size sought was 214 (Arkin & Colton 1962, p. 22). A master list of all swimmers entered in the meet was then compiled, and a table of random numbers (Arkin & Colton 1962, p. 158) was used to select 214 names to be used in the survey. Ultimately, 179 surveys, or 83.6 percent, were completed and returned. This number included 105 of 139 schools entered in the meet, or 75.5 percent.

The procedure for gathering the data was developed to get as complete a return of surveys as possible within the three days of competition. It was decided that the best way was to have individual members of the research team approach the swimmers, ask them to fill out the survey form, and return the completed form to a central location. Coaches had previously been made aware of the survey and of the fact that it had national support, and they were asked to have their swimmers who were part of the sample be cooperative in filling out the forms.

A group of undergraduate physical education majors volunteered to be part of the survey team gathering the data. Each was given a list of swimmers to contact, using the swimmer's name, school, and events entered as guidelines. They were instructed to be polite in their requests, not to interfere with the swimmers during their preparation for their swimming events, and not to substitute other swimmers for those on the sample list who were not in attendance. The completed questionnaires were carefully checked against the master list as they were returned, to ensure proper sampling techniques and prevent duplication.

RESULTS

Results of the survey are presented in Tables 1 through 7. In all tables the results are given in percentage form.†

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*The sample size of 229 was considered to be conservative, or large, as based on a 0.50 proportion of attributes in the population.

†Same totals do not equal 100 percent because figures were rounded to the nearest tenth of a percent.

Table 1. Descriptive Information about Women Attending the 1975 AIAW National Swimming Championships

	Mean	*Range*
Age	19.22	17 - 23
Height	5′ 6.9″	4′11″ - 6′1″
Weight	133.46	101 - 180
Age began swimming competitively	9.68	3 - 19
No. years swimming competitively	9.14	1 - 15

Table 2. Academic Majors of Women Attending the 1975 AIAW National Swimming Championships

HPER:	25.7	Behavioral Sciences:	10.0
Medical Sciences:	15.6	Education:	9.5
Humanities:	13.4	Business:	3.9
Sciences:	12.3	Undecided:	9.5

Table 3 shows that most swimmers at the meet were freshmen, and more than half had been on a college women's swimming team for only the current year. This is most likely an indication of the push during 1973-74 to augment women's sports in colleges for the 1974-75 school year, especially at state-supported institutions. The total number of schools with swimmers entered in the meet was nearly double that of the 1974 meet, and as a result many of them would have swimmers competing for the first time.

Table 3. Class Ranks and Years of College Competition and Financial Aid of Women Attending the 1975 AIAW National Swimming Championships

	Fresh.	*Soph.*	*Jr.*	*Sr.*
Present class rank:	41.8	22.9	22.9	12.2
Years	1	2	3	4
For how many years have you been on a college women's swimming team?	51.3	23.4	18.4	6.7
For how many years have you been on an athletic scholarship or grant?	14.5	3.9	0.5	0.0

As to the training background of the women competing at the nationals (Table 4), AAU programs had by far the greatest influence in training swimmers. It should be encouraging to those in public education, though, to note that more than half the girls did swim on high school girls' swimming teams, although as Table 5 indicates, not all girls attending high schools with girls' swimming teams swam on those teams. It should also be of interest that 11.7 percent of the girls swam on or with their high school boys' teams, so apparently many men are willing to help find opportunities for girls to compete.

Table 4. Training Background of Women Attending the 1975 AIAW National Swimming Championships

Prior to college, what was your main type of training in swimming?

AAU:	66.4	Combinations of AAU, YM(W)CA, and H.S.:	12.3
YM(W)CA:	9.5	Other:	0.5
High School:	4.5	None:	2.2

Table 5. High School Swimming Background of Women Attending the 1975 AIAW National Swimming Championships

	Yes	*No*
Did your high school have a swimming pool?	43.0	56.9
Did your high school have a girls' swimming team?	59.3	40.7
Did you swim on a high school girls' team?	54.7	45.2
Did you swim on a high school boys' team?	11.7	83.2

The element of recruiting was also investigated in the survey (Table 6). Although the 1973-74 AIAW Handbook (1973, p. 12) stated that recruitment of student athletes was not approved, 14.5 percent of the swimmers admitted to being recruited to swim on their college teams. The point of who made the first contact in the recruitment process was not investigated, but apparently this percentage of women felt that recruitment of some nature was a factor in their decision to swim on their college team, despite the AIAW rule prohibiting it.

Table 6. Recruiting and Financial Aid Information about Women Attending the 1975 AIAW National Swimming Championships

	Yes	*No*	*DNA*
Were you recruited to swim on your college team?	14.5	84.9	0.5
Are you attending college on some type of nonathletic scholarship or grant?	16.2	82.6	1.0
Are you attending college on some type of athletic scholarship or grant?	18.9	81.0	—
Were you attending college on some type of athletic scholarship or grant prior to this year?	4.4	92.2	3.3

Table 6 also reports that 18.9 percent of the women were attending college on some type of athletic scholarship or grant. This percentage is of special interest because of the push in 1973-74 for financial aid for female athletes. Prior to that year, only 4.4 percent of the women were on financial aid, so there was an increase of 14.5 percent in one year. (A breakdown of the number of years women have been on athletic scholarships or grants is given in Table 3.) This figure will probably continue to rise.

Five to fifteen years ago, when many women's records were being set by teenagers who retired from competitive swimming at a pre-college age, it was believed that the women would probably have continued swimming if college-level programs had been available to them. The first item in Table 7 suggests that more than 70 percent of the women competing at the nationals would not have continued swimming if they had not had an opportunity to compete at the college level.

Table 7: Information about College Attendance and Competition of Women Attending the 1975 AIAW National Swimming Championships

	Yes	*No*	*DNA*
Would you have continued swimming competitively if you had not had an opportunity to compete at the college level?	25.1	71.5	3.3
Would you have competed in college level swimming if you had not been offered an athletic scholarship or grant?	60.3	6.7	32.9
Would you have attended your present college if they had not had a women's swimming team?	54.1	44.1	2.1
Would you have attended your present college if you had not been offered an athletic scholarship or grant?	50.2	12.2	37.4
Do you anticipate graduating from college within four (4) years of the semester you began college?	79.3	20.1	0.5
In your opinion, does your college women's swimming team have equitable access to and use of the pool facilities in your school as compared to the men's team?	62.5	35.7	1.6

The next item in the same table indicates the desire of women to compete after high school as a function of their drive for sport and competition. This should not be seen as a justification for dropping or decreasing financial aid for women, as the results are likely to be similar if college male athletes were asked the same question. In fact, the results of this item should lend support to the argument that competition is not an exclusively male characteristic and that women too seek competitive activities.

Table 7 also shows some of the bases for women's decisions regarding choice of schools. More than half would have attended their present college even if the school had not had a women's swimming team or offered financial aid to women athletes. In fact, it may be likely that in many cases schools were chosen because no financial aid was available, and so the women as students were left with the option of attending state-supported institutions where tuition and expenses were affordable, regardless of the availability of competitive swimming. However, it should be pointed out that even if this expense factor might have been the reason for selection of a college to attend, the women were anxious to swim when college women's swimming teams were made available in more schools, as indicated by the number of first-year college competitive women swimmers.

Finally, the swimmers commented on pool time afforded in their schools as compared to the men's teams. Nearly two thirds said that their team had equitable access to and use of the pool facilities in their school. However, many of those who answered "No" did so with an additional comment. The implication is that even though well over half the women felt that they were getting fair pool time and use, those who were not were far from being in an equitable situation.

Following is the questionnaire used in the survey reported in this article:

AIAW NATIONAL SWIMMING CHAMPIONSHIPS

INFORMATION SURVEY FORM

Please respond by circling the best answer for you or by filling in the blank space. "DNA" stands for "Does Not Apply."

1. What is your age? 16 17 18 19 20 21 22 23/over
2. What is your height? _____ft. _____in.
3. Weight? _____lbs.
4. What is your present class rank? Frosh Soph. Jr. Sr.
5. What is your major course of study? ____________________
6. At what age did you begin swimming competitively?
   5 6 7 8 9 10 11 12 13 14 15 16 17 18
7. For how many years have you been swimming competitively?
   1 2 3 4 5 6 7 8 9 10 11 12 13/more
8. For how many years have you been on a college women's swimming team? 1 2 3 4
9. Did your high school have a swimming pool? Yes No
10. Did your high school have a girls' swimming team? Yes No
11. Did you swim on high school girls' team? Yes No
12. Did you swim on a high school boys' team? Yes No
13. Prior to college, what was your main type of training in swimming? High School AAU YM(W)CA None Other__________
14. Were you recruited to swim on your college team? Yes No DNA

15. Are you attending college on some type of non-athletic scholarship or grant? Yes No DNA

16. Are you attending college on some type of athletic scholarship or grant? Yes No DNA

17. Were you attending college on some type of athletic scholarship or grant prior to this year? Yes No DNA

18. If "Yes" to either 16 or 17, for how many years have you been on an athletic scholarship or grant? 1 2 3 4 DNA

19. Would you have continued swimming competitively if you had not had an opportunity to compete at the college-level? Yes No DNA

20. Would you have competed in college-level swimming if you had not been offered an athletic scholarship or grant? Yes No DNA

21. Would you have attended your present college if they had not had a woman's swimming team? Yes No DNA

22. Would you have attended your present college if you had not been offered an athletic scholarship or grant? Yes No DNA

23. Do you anticipate graduating from college within four (4) years of the semester you began college? Yes No DNA

24. In your opinion, does your college women's swimming team have equitable access to and use of the pool facilities in your school as compared to the men's team? Yes No DNA

CONCLUSIONS

Several conclusions present themselves at this point. First, information about athletes can be obtained at a national competition if proper survey procedures are used. The key seems to be in the method used to collect the data from individual athletes during the scheduled dates of competition. That is, a simple request of athletes and/or coaches to fill out some questionnaires and return them at their convenience does not seem to generate sufficient response to be of much use. Rather, athletes must be approached individually and asked to turn their attention to something other than the immediate competition for a few minutes. Careful tabulation must be done during the course of data collection so that duplication of information and effort does not occur.

A second point is that the data definitely show that the presence of swimming teams at colleges and universities affected decisions made by college-level female athletes. In particular, both participation and attendance were shown to have depended in large part on the opportunity to compete at the college level and, in many cases, to attend a particular school in order to compete. There seems to be some legitimate value in women's collegiate athletics, at least for swimming, based on the fact that opportunity seems to have promoted participation.

Third, responses about recruiting raise some interesting questions. Can the figure reported in the data be considered accurate, especially in light of the AIAW rule on recruitment? Will this figure be likely to grow, and if so, what is likely to be the response of the AIAW to the recruitment situation? The AIAW has already revised its rules on recruiting to make it permissible; are more comprehensive regulations for dealing with recruiting violations soon to follow?

Finally, it is suggested that other information might be of interest and obtainable through similar sample survey procedures at other national competitions of AIAW. For instance, what percentage of the women paid all or part of their way to the national championships? What will be the percentage of women on athletic financial aid five years from now? Who are the coaches of the college women's swimming teams (men or women?), and what is their coaching background or training?

The AIAW, being relatively new as an organization, has great opportunities to do research on female athletes and on women's athletics. Doubtless, supporters of movements to encourage greater female participation in all areas of our society would welcome research showing that this support and participation is in fact occurring in one area where it traditionally has been neglected.

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A CROSS-CULTURAL COMPARISON OF SOME OUTSTANDING SPORTSWOMEN*

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In recent years, psychologists and sociologists have become increasingly interested in the relation between human behavior and social conditions in general, and in female behavior specifically, as it is influenced by the sociocultural environment. The issue of female behavior in achievement-oriented situations has been the focal point of many studies. Horner (1968), Maccoby (1963), and Hennig (1971), among others, observed females in the pursuit of various life goals, in intellectual and business endeavors, while Harris (1971), Ogilvie (1967), and Balazs (1975) concentrated on females striving for excellence in sports and athletics.

Comparative research across cultures of such human traits as the need to excel and the drive to compete, however, seems to be relatively neglected. When it comes to investigations of these traits in women, comparative data is almost nonexistent. The purpose of this investigation was to study women in a specific achievement-oriented situation — *in sports* — and to draw parallels in the psychological and social development of athletic high achievers in differing sociocultural mileus.

Hungarian female athletes were selected as a group in order to compare them with a similar group of Americans. First, Hungary has a history of impressive sport achievements of its women. It was hoped that in a society where woman athletes are successful, there would be interest in researching female performance and behavior in sports and, as a result, scientific data would be available for comparative purposes. Second, the author is a native of Hungary and thoroughly familiar with the culture and language of that country, both crucial factors in conducting cross-cultural investigations.

A survey of literature revealed that Hungarian psychologists, physical educators, and coaches have done little work in the area of female athletic performance.[1] Most publications about women in sports deal with the physiological differences between males and females (Kiss 1964) or present physical education programs for the schools (Konopka 1965), and Hungarian writers have little new to say. Some authors (Varga 1969) still recommend sports for women as a practical means to the age-old goal of producing healthier babies more easily. Others (Kantra 1966) talk about the "soothing effect of sports on the female psyche," which was a major proposition of the Victorian era.

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*This research was carried out partly in the United States in 1974 as the author's doctoral dissertation, and partly in Hungary in 1975 with Dr. Balazs as principal investigator and Professor E.T. Nickerson as project advisor, Boston University, School of Education.

[1] The central sport-library in Budapest, the largest in Hungary, lists 13 publications under the heading Women in Sports. Five of these were published before 1945.

Marxist ideology — the underlying political force in Hungary since 1945, which applies both to education and to psychology (Rahmani 1974; Rubinstein 1967) and advocates equality among the sexes — seems to have little bearing on the rights of women in sports. Influential writers of today's Hungary have few new ideas to convey to the American reader. Lekarska (1964) deplores the fact that "women still have to fight for their basic human rights" and asks, "Why are women still hindered in sports, in something no one should be deprived of?" She describes the average girl as "the smiling doll, alluring and empty-headed, whose sole purpose in life is to fetch a husband." Kiss (1964) takes a historical-political view and remarks that "in feudalistic-capitalistic societies it was religion — and it still is — that prevented women from going out for sports." She labels capitalism as a "system of false morality," responsible for keeping woman down. Regdanszky (1963), in a more objective vein, takes a look at women's position in sports and notes that there are no studies on female athletes because "the researchers are males and they seem to be interested in researching male athletes." In another chapter, the author analyzes women's emotionality "manifested in tears, crying and hysterical sobbing not uncommon among female athletes after competition." She emphasizes *after*, because during competition "the female athlete certainly holds her own." Regdanszky also has a word for coaches. "Don't just train and demand, but educate these girls too." She underlines the character-building potentials of sports.

The area of study that we have lately come to see as women's psychology is sorely neglected in Hungarian sport psychology. One of the latest publications, a comprehensive book called *Sportpsychology* (Rokusfalvy 1974), does not even mention women in sports. Clearly, studies are needed in Hungary, as elsewhere, and a closer look is needed at issues concerning not only the sportswoman but women in general. It is also evident that looking at the same problems with a cross-cultural perspective would widen the understanding of some of the global social issues of today.

PROCEDURE

Two identical studies were conducted. The first (Balazs 1975), completed in 1974, had a sample group of 24 U.S. Olympic female champions who competed in the 1972 Olympic Games as swimmers, gymnasts, skiers, and track and field athletes. The second, conducted in Hungary in 1975, included 24 Hungarian female athletes, who also competed in the 1972 Olympic Games. They were swimmers, gymnasts, track and field athletes, and fencers. (Hungary has no ski team.) All the subjects were personally and individually interviewed by the researcher. The Hungarian athletes were first contacted by their coaches with whom the author met in Hungary and explained the purpose and the procedures of the investigation. Meetings with the subjects were then arranged at various places in Budapest. The interviews were held in Hungarian and were tape-recorded.

During the conversations, a wide variety of topics was discussed concerning the athletes' lives from early childhood to the present, following the general line of the American study. Each athlete was also asked to fill out a Personal Data Questionnaire (PDQ), which was a biographical inventory developed by the researcher and translated for the Hungarian sample. All of the subjects then completed a psychological test called the Edwards Personal Preference Schedule (EPPS), also translated into Hungarian.

The research was organized so that first the factual data obtained from the PDQ was presented, then compared with the findings of the American sample. Second, the clinical material of the interviews was analyzed according to the life-periods of childhood, adolescence, and young adulthood. In both studies, it was possible to identify a number of developmental themes that emerged and pervaded through the life-stages. These dynamics were recorded and compared. Third, the scores on the EPPS were arranged into a personality profile for each individual and finally averaged into a group profile. At the end, a parallel was drawn between the American and the Hungarian group profiles.

RESULTS

The data on the PDQ revealed that 73 percent of the Hungarian athletes were first-born children or first-born daughters, compared to 54.2 percent of the American sample. Both scores are high and correspond to similar findings of other studies (Douvan 1971; Hennig 1971; Horner 1968) on high achievers. The majority of Hungarian girls came from families with two or more siblings, compared to four or more siblings for the American group (Figure 1). Looking at the data concerning the athlete's age, one finds that the American girls started competing earlier (Figure 2) and made it to the top at a younger age than their Hungarian counterparts (Figure 3). The average age of the American group at the 1972 Olympic Games was 20.8 years, while it was 22.1 for the Hungarians.

Fifty percent of the Hungarian girls and 25 percent of the American girls were married at the time of the interview. The average age at marriage was 20.5 years for the Hungarians, 21.9 years for the American athletes. Of the American girls, 83.5 percent listed themselves as students, while 54 percent of the Hungarian competitors were in this category. No one had full-time employment at the time of the Olympics, but four Americans (16.5 percent) and 11 Hungarians (46 percent) reported holding part-time jobs.

Among the American parents there were as many recreational participants in sports as spectators (12 each), while the Hungarian parents were predominantly spectators and viewers of sports (22 in this category). Among the siblings, almost equally high numbers of athletic competitors were found: 16 for the American, 14 for the Hungarian sample.

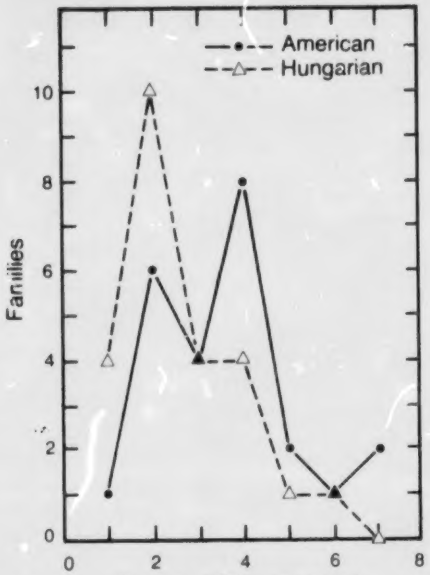

Figure 1. Children in Family

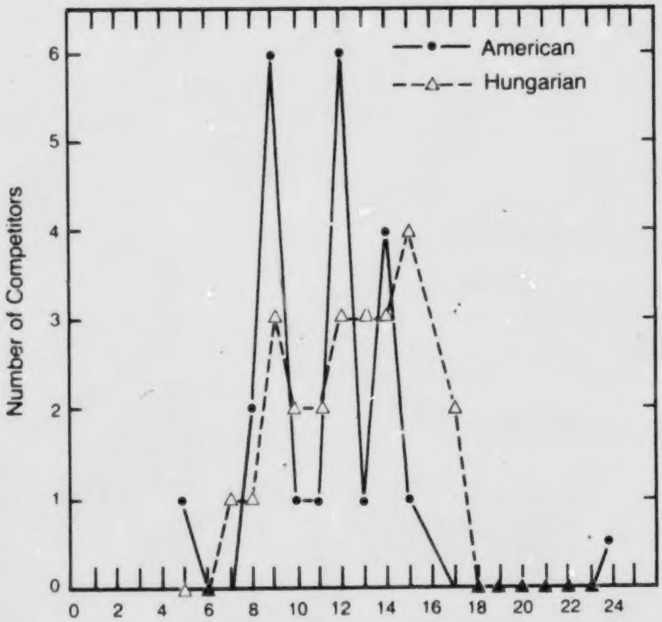

Figure 2. Age at First Competition

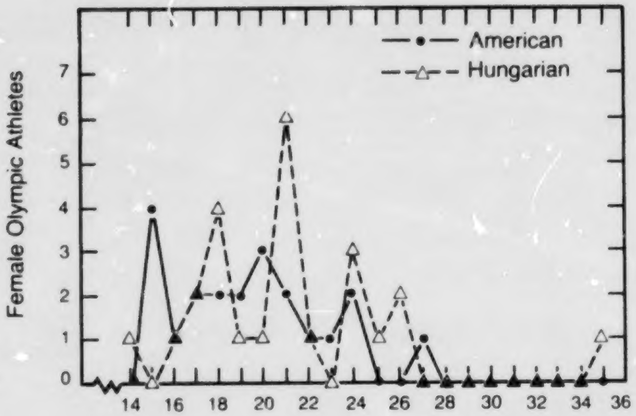

Figure 3. Age at 1972 Olympics

Analysis of the clinical data (case histories, based on the interviews) suggested that there were several identical patterns in the developmental dynamics of the two groups. All the girls talked about themselves as energetic and very active children ("tomboys," as the American girls said it, and for which there is no word in Hungarian). They had an early, strong drive to excel, and they used almost identical words to describe it. Characteristic American quotations: "Since I can remember, I always wanted to be the best in something. It was in me." "I had this strong inner drive to do something better than anybody else." A characteristic Hungarian quotation: "I always had this inner drive to push myself further and further. Not only in sports but in just about everything in life. I am always aiming for the maximum. I have to be the first one. Second place just wouldn't do. In school work, before an exam I decide that I have to have the absolute highest mark. An A-minus is out of the question. It has to be A-plus." The desire to achieve something, to excel, was one of the main developmental themes that pervaded the life histories. It characterized every person in this study.

Another theme, clearly recurring in almost all of the cases, was the desire to move. "I love to move, I love to be in motion. I feel physically well when I move," said one of the Hungarian girls. Another said, "Movement gives me satisfaction, I love it. It is a creative work for me to express myself in motion. There is rhythm, there is beauty in the moving body. I adore it." Still another remarked, "The joy of movement is the main force that keeps me going."

The need for physical activity and the apparent satisfaction it brought was combined in these young athletes with the need to master something well, to become good in something. Goals were set early in life, and then they were followed through consistently. The ultimate question of why one does it was almost uniformly answered: "I do it because I love it. To go that far is almost impossible unless you love what you are doing." "I can't imagine doing anything else that would give more satisfaction than what I am doing."

Similarities in family dynamics were also found between the two groups. Families were remembered as supportive. "I could always count on my family; they were all behind me." "All of my family was with me in what I loved to do." But beyond the support and solidarity there were also expectations. As one of the Hungarian girls said, "In my family it was simply assumed that we have to do our very best. All of us understood it. And we were really on top of our classes, straight 4-point average for all of us. That's how one started out in school and that's how these expectations were followed through in just about everything one did in life." The American girls, too, conveyed the feeling: "Only doing the very best would do in my family, nothing less." "I couldn't get away with anything less than top performance in school work or anything else."

While the atmosphere of the families had striking similarities in the two countries, there were also interesting differences in the family constellations. The main difference centers around the father. It is a well documented fact that fathers play a crucial role in the lives of daughters. Findings of several researchers (Hennig 1971; Douvan 1971; and others) affirm the significance of the father — especially in the lives of ambitious, successful females. In the American sample, fathers were remembered with an emotional tone of voice as "the most important person in my life" who was "always available when I needed him, and I could always count upon him," and "he was the main motivating force in my life." In contrast, the majority of Hungarian girls had very little to say about their fathers. "He liked my being in sports,""he was strict," and "he wanted me to succeed," but not much more. Who then filled the need of the father-figure female children — especially high achievers — seem to need? This person turned out to be grandfather.[2] Almost all the Hungarian girls had grandfathers of whom they had fond memories. "Grandpa was the most important person in my life. He loved me and I sure loved him." "I could never have made it without my grandpa; he kept an eye on me and on everything that concerned me. He was the main motivating force in my life." The words describing grandfathers were almost identical to the ones the American girls used to talk about their fathers.

The Americans remembered their parents as "available" and "always around when I needed them"; the Hungarians regarded their grandparents as the ones who "stood by" and "cared a lot." Nuclear family in one country, extended family in the other — but clearly it was the family that played a crucial role in the personality development of these girls. It was the family unit that carried values, set ideals and patterns for identification. The subjects seemed to be aware of this fact and of its importance.

Another interesting observation of this study centers around the coach. It is often suggested that the coach, for many athletes, is a father figure, a surrogate father (Balazs 1975). In the sample, it appeared that the relation the subjects had with their father was mirrored in their relation with the trainer. The American athletes, most of whom felt extremely close to their fathers, reported a similar close and rewarding relation with their coaches. For the Hungarians, on the other hand, where father-daughter relations were more distant, coach-trainee relations, too, appeared to be such. Most of the Hungarian athletes described their coaches as hard-driving and demanding but did not hesitate to add that "perhaps he has to be so strict to bring out the utmost." The coach was respected for his knowledge; his authority was never questioned; he was often liked — but seldom loved. In contrast, the American girls talked in superlatives about their coaches: "He is the best." "I love him." "I would do anything for him."

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[2] As a word of explanation, in today's Hungary the social system expects all people, men and women, to work full-time outside of their home. The general pattern of living is that husband and wife leave early in the morning and are gone all day. The offspring are left at various day care institutions or, if fortunate, with grandparents.

Where differences of special interest surfaced in this investigation, they were in the realm of social interaction, in the different ways the two societies expected the subjects to conform to the prevailing norms and values. During childhood there was no problem; in the United States as well as in Hungary the valued behavior for youngsters is to be physically vigorous and to do well in school. Both boys and girls are encouraged to excel physically and intellectually. With the onset of puberty, however, the American girls found themselves confronted with a new set of norms, defined as "feminine norm," meaning nonambitious, noncompetitive, passive, submissive. Coleman, Konopka, and other sociologists — who call the United States the most peer-oriented society in the world — write about that stage of life as usually the end of self-initiated motivation for the American girl. The person with ability and goals is looked upon by peers with suspicion, and behavior that is divergent from society's norms and values becomes a target for conforming. This is the time when most girls give up personal ambition and the planning for achievement-oriented life goals.

The adolescent years were remembered by all the American subjects as difficult times. "It was awfully hard. Everybody in school was uneasy about what I was doing. Why should a girl want to be a first-rate athlete? Boys and girls just couldn't understand that I have something special going, that I have goals. I was regarded as different. I didn't smoke, didn't hang around the drugstore; I just didn't have the time for these things. Kids teased me. Wow! Look at those muscles! Hey, wanna wrestle? It was very hard. I felt alienated. I felt left out."

The Hungarian girls did not remember such negative experiences during adolescence. Society's expectations toward boys and girls continued to be the same. The message seemed to be to do something worthwhile, have goals. "The school was proud of us, and boys and girls admired us for our achievements in sports. Everybody seems to appreciate it if you are excellent in something, and athletic girls are usually extremely popular. People seem to admire us for being able to do something well."

Social life and dating were added problems for the American girls but apparently presented no difficulty in Hungary. Elisabeth Douvan, in writing about adolescents, remarks that the dating habit of the American girl is extremely limiting, with a concentration on the most superficial aspect of life — competing for a date. It happens at a critical time of development, when the search for identity and self-concept goes on with full intensity, when norms are internalized and patterns of behavior are permanently set.

The American girls said, "Here in the United States if you are 13 or 14 and all of your friends are dating and going to places with boys, a girl athlete feels terribly separated. Many girls simply give up their sports; social life is more important to them at that time of life. It is almost a choice: do you want to be popular or do you want to become a first-rate athlete?"

In contrast, the Hungarian girls said, "Boy-girl relationships don't start early in our country. A lot depends, of course, on the family and on friends. I had a sister who was terribly involved in music, just as I was in sports, and my friends all seemed to have some burning passion for something. We had simply no time — and frankly no desire — for the so-called social life. I didn't go out with boys until I was well over 17. It would have been out of the question to date earlier. Nobody did."

The Hungarian subjects started dating later, but they married early. Several of the girls married at the age of 18 and, as the interviews revealed, they often married their very first date and had the first child right away. Now the Hungarian athlete experienced a crisis similar to the one the American subjects reported during adolescence: a conflict between personal goals and societal expectations. Girls who until marriage were admired for their achievements and encouraged in their endeavors suddenly found themselves measured by a new set of norms. They now were expected to behave according to a different code, to be family-centered, nurturing, nonambitious. The quotations of the Hungarians sample aptly described the situation:

> The moment you marry, everything changes. With the change in your legal status, your outlook on life has to change, too. From here on, society's values reserved for married women apply to you, too. That means that housework is your responsibility, childcare is your responsibility, and if you have personal goals and a need to fulfill them, that's just too bad. Because those will have to come after your other duties are all taken care of. Everybody agrees on that. That's the way it always has been and it shall remain just like that. In a marriage there is no room for the wife's ambition.
>
> My husband is also a competitor, a gold-medalist Olympian. He knows more than well what it takes to stay in top form, to hold your position in sports. You have to have rest periods during the day; you have to be in bed at a decent time so that your next day's workout goes well. My husband certainly lives by these rules. But when it comes to me, the same common-sense things somehow do not apply. He seems to forget that I, too, would need a short rest period during the day and that it would be just as important for me to be in bed at 10 o'clock if I have a competition coming up next day. But at 10, I am still in the kitchen making preparations for the next day for the baby, because if I don't do them, they are not going to be done. My husband doesn't seem to realize that. He never offers to do anything extra. Nobody does. It's just not being done. Changes? I don't know if they will ever come. Perhaps in three, four generations' time.

> Childrearing is such a problem. Sure we have good day-care centers, but they are good only when the child is well. And I have a sickly baby; she seems to come down with a cold every other week, and then it's a disaster. I go around frantically asking and begging relatives and friends if somebody please would take her or would come over to the house. To have paid help is out of the question; it is so expensive, so rare. Naturally on these days my thoughts are not very much on my work. It is definitely harder for me to stay on the top than for my husband, whose main concern is strictly himself and his career. In fact, he is better off now that he is married. Me! I am seriously thinking of giving up sports. It is getting just much too much.

In the American group, where only six girls were married and none had children, these problems did not even arise. It appeared that with the passing of time, the Hungarian subjects' privileged position as first-rate athletes became curtailed, while the American subjects felt an increase of rights and acceptance. As the American girls proved themselves successful in sports, the social climate changed and they were gradually accepted as successful women, too. Some remarked, "Men have a lot of admiration for me now. People can't stop complimenting me for my accomplishments."

The findings on the psychological test (EPPS) revealed remarkable similarities in the personality make-up of the two countries' subjects. The group profiles were much alike (Figure 4), mirroring almost identical

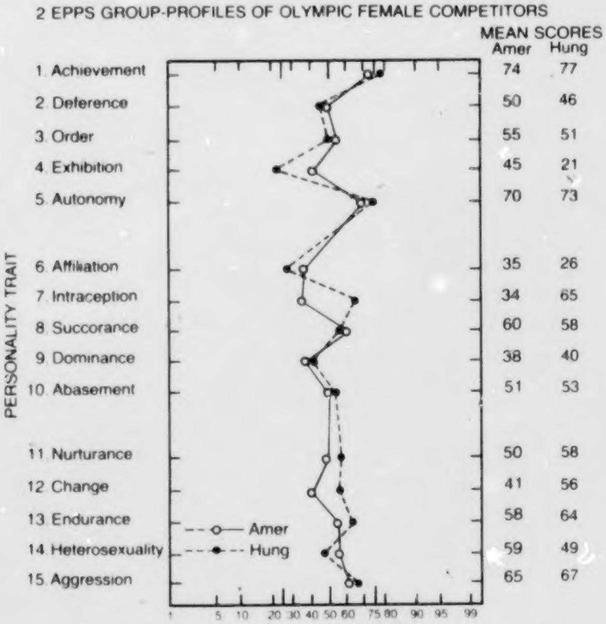

Figure 4. Percentile

characteristics. Especially apparent was the closeness of group scores (within 3 points) on Achievement and Autonomy, the two highest-ranking variables on the scales.

To interpret the EPPS test scores (according to Edwards' 15 mainfest needs), the subjects of this study were people with very high needs to do well, to excel (Achievement scale), and to make decisions for themselves (Autonomy). They were "stick-to-it" kinds of persons who liked to stay with a problem until it was solved (Endurance) and liked to pian in advance, to organize things before the task was undertaken (Order). They were willing to obey social rules and customs and were by no means the revolutionary elements of society (Deference). They were like the "average girl" in their feelings and emotions (Abasement) and had the need for friends as other girls did (Nurturance). They liked to do things on their own, with no particular concern as to how others regarded their action (Affiliation). They did not try to influence others, nor did they care to become leaders (Dominance). They had an average need for experimentation to do new things (Change). They liked to be considered attractive by the opposite sex and enjoyed the company of men (Heterosexuality). They had positive self-concepts (Aggression) but needed encouragement from those who were important in their lives (Succorance).

Where there was deviation in the two groups' scores, 22 points on Exhibition and 31 points on Intraception, the explanation may lie in the culture-bound qualities of these two variables. For example, a person who scores high on Exhibition likes to talk about herself and enjoys discussing her personal achievements. The American subjects scored lower than average on this variable, meaning that they did not like to "show off." They felt that "if you are good, your action will speak for it, and you don't have to brag about it." The even lower score of the Hungarian subjects reflected the general view of that country, namely that girls should be "prudent." The more outstanding a girl is, the more she is expected to display modesty, to "play it down" (which by no means seems to be the norm for the Hungarian male's behavior).

The discrepancy in the Intraception scores also deserves a note of explanation. Intraception is a complex scale dealing with the person's inner needs. It reflects the ability of self-analysis, of looking at oneself in a critical way. For the American girls, for whom the lowest score on the scale was on Intraception, this can be interpreted as maturity for self-evaluation and self-criticism. The Hungarian girl's much higher score reflects not necessarily a lesser degree of maturity or intellectual capability but a generally lower level of familiarity with psychology in that country. Terms such as *ego-strength, guilt feeling,* and *inferiority complex* were readily discussed by the American subjects but did not come up in the conversation with the Hungarian girls. In general, the author had the impression that orientation toward pyschology is less developed and practiced in today's Hungary than in the United States.

In all, the data acquired from the test (EPPS) seemed extremely consistent with the pattern of responses in the clinical research (interviews).

CONCLUSION

Cross-culturally, it appears that the outstanding female athletes of this study had remarkable similarities not only in their personality development and traits but also in family background and general outlook on life. Most distinguished was the high need for achievement, the desire to succeed, to excel.

Another trend common to the two countries was the attitude of the families. The nuclear families of the United States and the extended families of Hungary were both regarded as one of the main motivating forces by almost all subjects.

Even dissimilarities in the dynamics of social interaction seemed to hold a common trend: society versus the aspiring young female. In the United States, it was during adolescence that the subjects experienced the strongest pressure to give up goals, to conform, to be "like everybody else." In Hungary, it was not until marriage that the female athlete felt a serious conflict between the fulfillment of personal ambition and the fulfillment of society's expectations of her as wife and mother. In both cultures, the different norms for women and men presented the female subjects with a psychological conflict that males do not have to experience. The author is inclined to conclude that female ambition and social norms are not quite compatible. And goal-attainment — in sports and perhaps in other achievement-oriented endeavors — is just as difficult for women in the United States as it is in Hungary.

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PHYSICAL SEX DIFFERENCES: A MATTER OF DEGREE

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During the 1970s, controversy over what constitutes equal opportunity for the female in sports has been nationwide. Decisions have been made based on opinion, bias, emotion, and the "letter of the law." Rarely have these decisions been formed from a research-based rationale. What constitutes equity and what constitutes discrimination are not clear to the average person.

Almost all sports discriminate against those who are less strong and fast, regardless of whether they are male or female. Sport is selective of the stronger, faster individuals. Since males, on the average, are stronger and faster, they have an inherent advantage in those sports demanding strength, speed, and power. This advantage emerges with adolescence and the maturation of the endocrine system, which influences physical stature, masculature, and strength.

Biology is the starting point for any discussion of sex differences. Biology also demonstrates the identity of male and female, indicating similarities and the continuity in development (Oakley 1972). Interestingly enough, at every stage of development, the male and the female share the same plan for development. If we accept definite masculine and feminine physical prototypes, envisioning a continuum from the most masculine to the most feminine is perhaps the best way to understand human physical characteristics. In the normal male and female, beyond the distinctive reproductive organs where even the anatomical difference is more apparent than real, all characteristics are shared to some degree by both sexes. With the exception of the reproductive organs, no absolute distinction can be made between male and female physical characteristics. In almost all physical characteristics, the difference is only a matter of degree.

Prenatally, up to a critical phase in the development of the embryo, the sex is nonspecific. Sex dimorphism is determined by either the X or the Y sex chromosome provided by the male parent, which determines the destiny of the undifferentiated gonads. These develop into either a pair of ovaries or a pair of testicles. From this stage, the sex chromosome exerts no further influence upon subsequent sexual differentiation, and the responsibility is relegated to the influence of hormonal secretions — androgens produced by the testes of the male and estrogens produced by the ovaries of the female. As a matter of fact, further sexual differentiation is determined by the hormonal secretions of the testes. Without them, the fetus continues to differentiate to the development of the female because of the dominant estrogen environment.

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Throughout the prenatal development, the male develops more slowly than the female. At 20 weeks after conception, the male is already two weeks behind the maturation of the female. The newborn female's physical maturity is equivalent to the male's at four to six weeks (Hutt 1972) even though the average newborn male is both larger and heavier. On the other hand, the male tends to grow faster than the female during the fetal stage and continues to do so but with progressive deceleration until about seven months of age.

The growth and development of the male and female after birth follow a similar pattern during infancy and early childhood, their growth curves paralleling one another. The weight of the male exceeds that of the female by approximately 4 percent during childhood and height by approximately 2 percent, in spite of the greater maturity of the female. According to Rarick (1973), the male continues to be both heavier and taller than the average female of the same age until about eight years. Despite these advantages in height and weight, the male develops much more slowly than the female. The growth speed of the male can be two or more years behind that of the female. This is most apparent in preadolescence, when many females are larger than males. Bone ossification, dental maturity, as well as physiological and neurological maturity are reached sooner in the female.

While gains in height and weight proceed at fairly uniform rates during childhood, the increase in height is approximately twice that in weight. In the process, females tend to maintain their proportionately longer leg length in relation to trunk length until the end of early childhood. During this period, the male has an overall width advantage of the pelvis, while the female tends to have a general overall advantage in the width of the inner structure of the pelvis. The relative gain in shoulder width is approximately the same for both sexes during ages 6 to 10. During the first decade of life, the amount of muscle tissue and muscle development is practically identical for males and females.

In general, sex differences in physical size and ability are minor, with no significant difference observed among preadolescents. The female's advanced maturity provides her with an advantage in physical activities. Frequently females are capable of outperforming their same-aged males at this stage of development. The arguments for excluding girls on the basis of inferior abilities could not be supported in the early 1970s when the Little League was charged with discriminatory practices (Torg & Torg 1974). In court, the Little League was not able to demonstrate and support that significant differences exist between males and females of the age for Little League that would preclude the female's participation. Judge Pressler was "persuaded by a heavy preponderance of evidence that there is no substantial physiological difference relative to athletic performance between girls ages 8 to 12 on one hand and boys 8 to 12 on the other hand" (Torg & Torg 1974, p. 50). Based on the research and evidence available to date, there does not appear to be any support for differential treatment in sport and physical activity programs of males and females during childhood and preadolescence. This has great implications for curriculum and programs for boys and girls.

With adolescence and physical maturation, the physical characteristics of the male and female begin to spread out along the continuum of physical structure. There is a bimodal curve along this continuum with considerable overlap between. While one can say that on the average males are taller, bigger, stronger, and so on, one cannot draw any absolute line between what is characteristic of the male physical structure and what is characteristic of the female physical structure beyond the reproductive organs. In short, the similarities far outweigh the differences. However, these differences have specific implications for sport performance where strength, speed, and power provide the participant with an advantage. In general, the changes that occur physically to the adolescent provide the male with the advantages in these factors.

In examining the factors influencing differences in physical structure of males and females, one has to understand the influence of the endocrine system upon growth and development. Puberty in the female begins as much as two years prior to that of the male, producing a growth spurt during which the female grows faster and sometimes larger than the same-aged male. She reaches mature height soon after the onset of menarche, when higher levels of the female sex hormone, estrogen, cause the closure of the epiphyses in long bones. This cessation is also produced by sex hormones in the male, but much later — providing the male with the added advantage of several additional growing years which contribute to his relatively larger physical structure at maturation.

Sex hormonal differences between the male and female influence other physical developments that have implications for sport performance. Higher levels of estrogens in the female cause deposits of increasing quantities of fat in the subcutaneous tissues of the breasts, upper arms, buttocks, hips, and thighs. At birth females tend to have proportionately more fat tissue than males. Fat tissue in females increases at adolescence, while the male tends to decrease his already lower amounts of fat tissue during this stage of development. The increasing percentage of fat in the female produces the broadening of the hips and the curves that are generally characteristics of the feminine form. As a result, the relative proportion of lean body mass — that is, muscle and bone — to total body weight is less for the female. The relatively lesser amount of muscle in the female is not caused by the inhibitory effect of estrogen but by the absence of the higher level of the male sex hormone, androgen. Increasing levels of androgens in the male during puberty produce greater muscularity and more prominent muscle definition. The female's lesser muscle mass is further masked by greater amounts of subcutaneous fat than observed in the male. The higher percentage of fat in the female increases her ability to retain body heat in the cold; she is also more buoyant. This difference in percentage of fat may influence heat dissipation, where females appear to be less efficient. They do not begin to sweat until their bodies are two to three degrees warmer than the male. In addition, their sweat glands are not as productive. Whether this is a result of not demanding them to function because "horses sweat, men perspire, and ladies glow" or whether it is a sex-related difference is not clear. Perhaps greater consideration should be given to females working or exercising in hot environments until a better understanding of their response to heat stress is reached.

Higher levels of female hormones also activate the menstrual cycle; this fact has probably caused more misconceptions about differences between males and females than any other characteristic. There is little reason for concern in the healthy female; menstruation is a normal function and should not cause any marked alteration in lifestyle. The effect of menstruation on athletic performance is questionable; gold medals have been won by female athletes during every phase of the menstrual cycle, and many athletes have produced their own personal best performance while menstruating. Pregnant athletes have performed with success in Olympic and other competitive athletic events without problems. In short, performance decrements are not generally anticipated, and restrictions in physical activity of normal, healthy females do not appear warranted.

During puberty the male's increased levels of androgen transforms his body into that of a mature man. The delayed growth spurt, as compared to the female, provides the male with a longer growing period which, among other things, allows the legs and arms to grow longer proportionately to his trunk length. A rapid increase in height is accompanied by an increase in the shoulder width. The skeletal structure becomes more dense and heavier, and marked development of the skeletal musculature contributes to his increasingly greater body weight. His relatively lesser amount of fat tissue is reduced even further during puberty, resulting in a higher ratio of lean body mass to fat tissue than in the female. Increased physical vigor and strength accompanies the muscular development which reaches maximal levels soon after the end of puberty. This increase in the male's strength is probably more the result of quantitative rather than qualitative change in musculature. The increase in strength is most apparent in the upper extremities, less so in the trunk, and appears to be absent in the lower extremities when compared to the female. Wilmore (1975) has suggested that females are capable of developing leg strength comparable to that of the male when participating in similar strength training programs. Foreman (1972) reported that a female was capable of pressing more weight on the leg press than any male tested on the Universal Gym. Wilmore (1975) demonstrated that males continue to develop greater shoulder and trunk strength than females on the same weight program. Further, they exhibit significant muscle hypertrophy that is not observed in the female. The higher levels of androgens in males produce the greater muscle mass, greater shoulder and trunk strength, and the ability to "bulk up" with weight training. On the same exercise and weight training programs, females tend to increase at approximately the same percentage as the males. However, males are generally stronger in the shoulders and trunk to begin with; therefore, the females still fail to close the gap. The fact that there appears to be no significant difference in the potential strength development of the legs in the males and females when training and conditioning programs are similar has great implication for sport performance, especially in those sports where the assumption has been that females were more vulnerable to knee and ankle injury because of lesser strength capacity.

When comparing males and females past puberty, the males are generally taller and heavier. Their larger size, greater vital capacity and cardiac output, along with relatively lower heart rates, provide an inherent advantage in strenuous activities. Physically, the average male is stronger and faster because of his additional muscle mass and longer levers. He is, therefore, capable of generating more power, which gives him a decided advantage in most sports. His wider shoulder and longer extremities in relation to the trunk are mechanically superior to the female; the larger shoulder girdle results in a higher center of gravity. In addition, the male generally has a greater ability to deliver oxygen to the working muscle because of the larger lung surface, larger heart, and higher hemoglobin. When measurements of maximal oxygen consumption are based on total body weight, the male is more efficient because he has less fat tissue to which oxygen must be supplied. The female must deliver oxygen to her fat tissue as well as her working muscle, which decreases her efficiency.

The average female is physically smaller than her male counterpart and generally has a longer trunk in relation to her leg length. Her center of gravity is usually lower than the male's, because of smaller shoulder girdle and increased pelvic development. The smaller chest, lungs, and heart, combined with the lesser chest muscle development, reduce the female's vital capacity. On the average, her oxygen uptake is less than that of the male because of the smaller heart and lungs, the lower hemoglobin levels, and the higher percentage of body fat.

Overall, the size and structural differences between and among males and females are only a matter of degree. This degree of difference is most probably produced by the variation of the ratio of androgens to estrogens in both males and females. Those males who have higher androgen levels than other males tend toward greater muscularity; some males can "pump the iron" all day for weeks on end and not bulk up to the same degree as others. At the same time, those females who are more muscular than other females may have a higher ratio of androgens to their estrogen levels than those females who are less muscular. More research must be conducted before this relation is established with conclusive evidence.

The variation in size and structure among and between the sexes produces marked differences in speed and strength and the ability to generate power. The higher the level of sport competition, the more selective the process is for those who are stronger and faster — for both males and females. In general, some sports for males take this factor into consideration; weight-classed wrestling, boxing, and football assist in equalizing the probability of success. Since most sports demand physical strength, speed, and power, the physical characteristics of the male are more responsive to the physical demands of sport and more conducive to superior performance. This is not to say that the female cannot participate at a high level; however, it does suggest that she may not be as effective as the male in meeting the task demands of those sports requiring strength, speed and power. For much too long we have equated power with skill, which has perpetuated the notion that females are less skillful than males.

This is not the case at all. Many females who are more skillful in executing the techniques of a sport will lose to a less skillful male who compensates for his lesser skill by applying his power advantage. Billie Jean King and Jimmy Conners are both highly skilled tennis players, but Connors is so much more powerful that King would have little chance of success playing against him. The point is that the female can develop high levels of skill in most sports and still have less opportunity for success against males who use their power advantage to compensate for lesser skill development.

It appears that biology is destiny in the development of strength, speed and power. This fact, along with the fact that organized sport is selective of the stronger, faster athletes, suggests that the post-adolescent male will have an inherent advantage in any sport that requires strength and speed. This calls to question the whole concept of what is equal in terms of athletic participation. Many argue that separate teams for males and females do not provide equal opportunity; however, when the inherent differences in the average male and female ability to generate power are understood,competing for positions on the same athletic team does not provide equal opportunity either!

While there are examples of females who are capable of performing at a higher level than some males, the percentage of females who can accomplish this is small. In general, competing for positions on the same sports teams will discriminate against the female, and few females will be capable of being selected for an athletic team. The more highly organized the sport team, the more selective is the process of the stronger, faster, and more powerful athlete. While some females may be able to participate successfully on mixed junior high school teams, and perhaps to some extent on selected high school teams, the chances of being able to compete with the adult male and being selected as a member of an athletic team at the college or university level are reduced considerably. Even with superior skills, she cannot compensate for her lesser speed, strength, and power.

Many individuals feel that the female will be able to "hold her own" with the male athlete once she has had equal opportunity in coaching, skill development, training, and so on. This suggests that the only reasons the female athlete performs at a level inferior to that of the male athlete are her lack of opportunity to develop at the same level and to the lack of social reinforcement for her skill development and high level performance. Based on the evidence available to date about the influence of endocrinology upon physical development, it appears that equalizing all other aspects of developing an athlete will not ensure the same effectiveness in performance of sport skills. This explains the continued practice of having only females pass a "sex test" for international competition. A genetic male masquerading as a female would have a decided power advantage competing against females. At the same time, the female masquerading as a male would have no advantage in athletic competition, so there is no need to screen her out of the competition.

The problem of the use of anobolic steroids among both male and female athletes is related to the influence of androgens upon the development of muscle mass. Many of the studies investigating the use of anabolic steroids among males have lacked proper controls and systematic assessment. Relatively few of these studies have evaluated plasma levels of androgens, and many have used too little anabolic steroids to effect an observable change — especially in studies using male athletes as subjects. It is quite possible that these males have circulating levels of androgens necessary to meet the highest thresholds of cellular and tissue response, so ingestion of additional steroids will not produce a significant change. And, since athletes are selected from among the stronger and faster, this hypothesis appears to offer a plausible explanation for the confused results of studies looking at the effect of inducing anabolic steroids. Since tissue threshold response to circulating hormones is critical to developmental changes, it appears reasonable to suggest that females may have a significantly greater response to anabolic steroids. I could find no reported research regarding the use of anabolic steroids among females. There are concerns, however, about the use of anabolic steroids among some female athletes. Lamb (1975, p. 4) stated, "The changes in muscle strength, body weight, and lean body mass caused by anabolic steroid treatment are probably greater than many would hope and somewhat less than many think. There is apparently a wide range of individual response to these drugs." I would like to suggest that the individual response may be related to the plasma levels of androgens and estrogens in both males and females. If circulating levels of hormones have already triggered the threshold response, increasing the levels will not have a significant effect; however, if the threshold response has not been triggered, then increasing the circulating levels will produce changes.

One has only to observe the response of hormonal treatment in transexuals to understand the physical alterations that can be produced in either direction by altering the ratio of estrogens to androgens. Changing the ratio in either the male or the female can produce developmental characteristics and physical configurations of the opposite sex. The fact supports the idea that the physical characteristics above and beyond the actual reproductive organs differ only by degree determined by the hormonal ratio. When this ratio is altered, the physical characteristics are also altered accordingly, depending upon the tissue response threshold.

In summary, the degree of physical differences observed in males and females may be explained by the degree of difference in the ratio of androgens to estrogens in both sexes. Beyond that, training, coaching, and experience can alter one's inherent capacity for physical performance. The greatest differences between males and females are observed from puberty through the active reproductive years when sex hormones are at their highest levels. During this period, males have higher levels of androgens which promote greater muscle mass, larger and more dense bones, and increased power to give them a decided advantage over females in situations demanding strength, speed, and power. Females have higher levels of estrogens, which shorten their growing period and increase fat tissue. The net result is a smaller and less powerful female compared to the male, on the average. Nevertheless, the female has the ability to develop high levels of skill in any sport and can compete successfully. Since the hormonal difference that exists between males and females will preclude the female from developing the same degree of strength, speed, and power as her equally trained male counterpart, there is good reason to suggest that equality in sport participation is not accomplished by having the female try out with the male for positions on the same athletic teams. Equality must come in other forms to ensure the female the same opportunities as the male in athletics. If there are positive benefits and if the experience in competitive sport is a significant and meaningful one to those who participate, then these are human values that should not continue to be the prerogative of the male even though he holds an inherent physical advantage in most sports. While females have continued to improve their performance with better training and coaching and more participation, it appears that the best of the females will never be able to outperform the best of the males in any activity involving strength and speed. Perhaps we are trying to make something equal that is not equal to start with in terms of potential performance in activities that demand strength, speed, and power.

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ATTITUDES TOWARD PHYSICAL ACTIVITY AS A FUNCTION OF THE APPROVAL MOTIVE IN FIRST-YEAR COLLEGE WOMEN

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Professional literature in the field of physical education is replete with studies investigating attitudes toward physical activity. The bulk of this research pertains to physical activity as it is related to programs of physical education. These studies have attempted to identify the variables related to attitude intensity, to investigate attitude change; and to isolate differences in attitude strength between groups. However, there has been little research reported in the physical education literature focusing upon the relation of personality constructs to the assessment of attitudes toward physical activity. Since a more definitive measure of attitudes toward physical activity is desirable, it was assumed that by identifying and controlling one psychological variable that was known to exert a powerful influence on the behavior of women, a more exact measure of attitude strength could be achieved.

The approval motive was selected as the independent variable because of (a) the repeated evidence in the psychological literature showing that women are more socially oriented in their interests, attitudes, and values than men (Anastasi 1958); (b) its demonstrated effectiveness and predictive utility in investigations using female subjects (Horton et al. 1963; Strickland & Crowne 1962); and (c) its motivational nature, which provides for the possibility of fluctuations in behavior in a variety of situations (Crowne & Marlowe 1964).

During the 1960s, Crowne and Marlowe (1960) postulated that the social-desirability "response set," a test-taking strategy of giving socially desirable responses to questionnaire items, was meaningful goal-directed behavior aimed at obtaining the approval of others. The approval motive construct implies that —

> (a) people differ in the strength of their need to be thought well of by others; and (b) for those whose need is higher, we could assume a generalized expectancy that approval satisfactions are attained by engaging in behaviors which are culturally sanctioned and approved (and by avoiding those responses which are not). (Crowne & Marlowe 1964).

Subsequent investigations using this construct have resulted in findings that characterize the individual with high need for approval as one who is quick to respond to the implied demands of authority figures (15); sensitive to the modal responses of peers and, when differing from this mode, inhibiting the expression of this difference and conforming to group opinion (Strickland & Crowne 1962); susceptible to attitude persuasion and change (Salmon 1962); cautious in risk-taking situations (Barthel 1964); sensitive to perceived situational cues and demands (Crowne & Strickland 1961; Marlowe 1962); and constricted and conventional in general response (Horton et al. 1963).

The individual with low need for approval appears to be the antithesis of the approval-dependent individual. This individual is characterized as presenting accurate and honest descriptions in self-evaluative testing situations. By not using the test-taking strategy of endorsing socially desirable descriptive statements, this individual is viewed as having less need for social approval. Moreover, in situations other than those involving tests, the behavior of the individual with low need for approval reflects a freedom from authority, conformity, persuasibility, and social pressures in general (Crowne & Marlowe 1964).

The social desirability of a questionnaire item or semantic differential scale may be viewed as an index of the cultural attitude toward the characteristic referred to by the item or scale. It has been suggested by Taylor (1961) that the social desirability variable can be viewed as an "overriding attitude, a single attitude that interacts with and sometimes masks other attitudes."

This study was designed to determine if women designated as high in the need for approval and those designated as low in the need for approval differ in their attitudes toward physical activity perceived as five subdomains. A second purpose was to examine the possible interactive effects of the two levels of the approval motive, high need and low need, and the two attitude-assessment conditions, neutral and experimental, on attitudes toward physical activity. Auxiliary purposes were to determine differences between attitude-assessment conditions and between an individual and group method of collecting data.

It was hypothesized that (a) women with high need for approval would differ significantly from women with low need for approval in attitudes toward physical activity perceived as five subdomains, and (b) there would be significant interactive effects between attitude-assessment conditions and level of approval motive.

REVIEW OF LITERATURE

Approval Motive

Based upon the assumption that individuals with high need for approval possess a generalized disposition to give socially desirable responses, Pervin and Lilly (1967) found that subjects with high need for approval rated themselves significantly higher on self-ideal ratings on semantic differential scales than did subjects with low need for approval.

Salman (1962) tested the hypothesis that subjects with high need for approval are more susceptible to attitude manipulation than individuals less motivated toward approval from others. The results showed that the attitudes of subjects with high need can be altered. Of particular interest to this investigator was the finding that the two groups, high and low need for approval, differed on the initial attitude measure.

In their first attempt to validate the approval motive construct empirically in a situation not involving test-taking, Marlowe and Crowne (1961) selected a conformity situation in which subjects performed a dull, repetitive spool-packing task. The results showed that approval-dependent subjects consistently expressed more favorable attitudes toward the tasks on a post-experiment questionnaire than the approval-independent subjects.

Using a verbal condition design, Crowne and Strickland (1961) found that approval-motivated subjects significantly increased their rate of "plural noun" responses under conditions of negative and positive reinforcement. In a second verbal conditioning experiment, an interview technique was used in which every positive self-reference emitted by the subject was reinforced by the experimenter. It was found that subjects with high need for approval produced significantly more self-references than approval-independent subjects (Marlowe 1962).

Strickland and Crowne (1962), using a simulated conformity situation, demonstrated that approval-oriented females yielded to perceived group opinion significantly more often than did females with low need for approval. This finding was replicated in a study employing an experimental situation in which the opposing majority were actually present (Crowne & Marlowe 1964). Of particular interest was the finding that the stronger the pressure to yield, the greater the conformity demonstrated by the subjects with high need for approval. Conversely, the subjects with low need for approval conformed less than usual to this strong pressure manipulation.

Horton et al. (1963) hypothesized that the behavior of approval-motivated females, in the absence of direct social pressure, would remain dependent upon conventional stereotyped social norms. The statistically significant finding was that females with high need for approval tended to respond to a word-association test with culturally stereotyped words.

Attitudes Toward Physical Activity

The most extensive study of attitude toward physical activity was a cross-national investigation of secondary school students conducted by Kenyon (1968). Kenyon's Attitude Toward Physical Activity Inventory (ATPA) with semantic differential scales was used to assess attitudes toward six subdomains characterizing physical activity as a sociopsychological phenomenon. The results of this investigation revealed statistically significant differences between males and females. Males exhibited the most positive attitudes toward physical activity as the pursuit of vertigo and as an ascetic experience, while females exhibited the most positive attitudes toward the subdomains of social experience and esthetic experience. A review of the United States female sample indicates the following ranking in terms of attitude strength: esthetic experience, social experience, health and fitness, catharsis, pursuit of vertigo, and ascetic experience. The need for approval construct was used as a behavioral correlate in this study. The tabular results indicate no significant relation between this construct and attitudes toward any of the subdomains for the female sample.

Using Kenyon's semantic differential approach, Delaplane (1969) found that the attitudes toward physical activity of college freshman males and females differed significantly with regard to specific subdomains. Males were significantly more positive than females in their attitudes toward the vertigo subdomain. The order in which the females ranked the subdomains was esthetic experience, social experience, catharsis, health and fitness, ascetic, and pursuit of vertigo.

Using a selected group of male and female Canadian championship athletes representing 10 sports, Alderman (1970) found little difference between the sexes in their attitudes toward physical activity. The rankings of subdomains by the female athletes were identical to those reported by Delaplane (1969).

Mullins (1969) investigated the attitudes of junior college males and females who differed in race and socioeconomic level. Using Kenyon's new ATPA Inventory, she found that males scored significantly higher than females on the subdomains of vertigo and ascetic experience. The rankings of subdomains by the female subjects placed social experience first, ascetic experience fifth, and the pursuit of vertigo last.

In a recent study, Zaichkowsky (1975) found statistically significant differences in the attitudinal responses of males and females after participation in required physical education classes. The women students showed a greater preference for physical activity as an esthetic experience, while the men students indicated a preference for the ascetic and vertigo dimensions.

The results of these investigations suggest that with little variation, males possess a more positive attitude toward the subdomains of vertigo and ascetic experience while females possess a more positive attitude toward the subdomains of social and esthetic experience.

METHOD

Subjects and Design

The approval motive subjects were 632 freshman women enrolled at the University of Oregon. From within the top and bottom 25 percent assessed on the independent variable, 196 subjects were randomly assigned to four treatment conditions: high need for approval with neutral attitude-assessment condition - 48 subjects; high need for approval with experimental attitude-assessment condition - 49 subjects; low need for approval with neutral attitude-assessment condition - 51 subjects; and low need for approval with experimental attitude-assessment condition - 48 subjects. This resulted in a 2 x 2 x 2 factorial design with two levels of the motivational variable, high and low need for approval; two levels of attitude-assessment conditions, neutral and experimental; and two levels of attitude data collection method, group and individual. Analyses of variance were computed for each of the three main effects and first and second order interactions for each of the five subdomains and for the total ATPA Inventory score. The degree of intensity and the directional focus of the attitudes expressed by the subjects with high and low need for approval were compared by computing the per-item mean and ranking the subdomains. Positive attitudes are reflected by values above the per-item mean of 4, while negative attitudes are reflected by values below 4.

Instrumentation

The Marlowe-Crowne Social Desirability Scale (1960) was used to measure individual differences in the initial strength of the need for approval. Individuals who score high on this 33-item true-and-false scale are viewed as placing a high value on the approval of others. Conversely, individuals who score low on the scale are viewed as placing little value on the approval of others.

Attitudes were assessed through the administration of the Kenyon Attitude Toward Physical Activity Inventory: Form DW (1968). This inventory, constructed for use with college women, assesses attitudes toward six subdomains characterizing physical activity. The five subdomains used in this study were social experience, health and fitness, pursuit of vertigo, esthetic experience, and ascetic experience. (See Table 1.) A sixth subdomain, catharsis, was not used because of its unestablished validity. In addition, a total inventory score was gleaned.

Attitude-Assessment Conditions

The psychologically neutral attitude-assessment condition was characterized as a group situation free from direct social demands. Directly exerted social influences were minimized by (a) using a paper-and-pencil instrument, (b) assuring anonymity for all subjects, and (c) excluding any verbal interaction among the subjects. Because of the nature of the assessment condition, subjects were denied the opportunity to compare attitudes with their peers. Every attempt was made by the investigator to create a psychologically relaxed and supportive environment. Constant positive reinforcement was given both verbally and nonverbally throughout the assessment period by the investigator, who moved freely through the group. The physical atmosphere was informally structured by using a gymnasium in which subjects were allowed to move freely to any location to complete the ATPA Inventory.

The experimental attitude-assessment condition was characterized as an ego-involving group situation in which direct social influence was exerted. An instructional set that emphasized the consequences of the subjects' attitudinal response behavior was achieved by informing the subjects, in a written statement read by the investigator, that (a) the results of the attitude study in which they were participating would be used for a feature article in the college paper; (b) they might be contacted by the paper for a personal interview based upon their responses to the ATPA Inventory; and (c) they should place their full name on the ATPA answer sheet. The investigator was presented as an authority figure, while every attempt was made to develop a psychological atmosphere that was formal, quiet, and serious. The physical environment was formally structured by arranging all chairs in the classroom in rows and placing all materials

Table 1. Rank Order Comparisons of Subdomains of Physical Activity for High-Need and Low-Need Groups by Neutral and Experimental Conditions and for Total Need

Need Level	Per-Item Mean	Rank	Neutral Assessment Condition	Per-Item Mean	Experimental Assessment Condition	Per-Item Mean	Total Need Group Ranking	Per-Item Mean
High Need for Approval	4	1	Vertigo	4.44	Aesthetic	4.52	Aesthetic	4.45
	4	2	Aesthetic	4.38	Vertigo	4.44	Vertigo	4.44
	4	3	Health/Fitness	4.07	Health/Fitness	4.15	Health/Fitness	4.11
	4	4	Social	3.84	Social	4.10	Social	3.97
	4	5	Ascetic	3.59	Ascetic	3.71	Ascetic	3.65
	4		Total ATPA	4.05	Total ATPA	4.22	Total ATPA	4.14
Low Need for Approval	4	1	Vertigo	4.62	Vertigo	4.39	Vertigo	4.51
	4	2	Aesthetic	4.10	Aesthetic	4.32	Aesthetic	4.21
	4	3	Health/Fitness	3.92	Health/Fitness	3.96	Health/Fitness	3.94
	4	4	Social	3.81	Social	3.67	Social	3.74
	4	5	Ascetic	3.37	Ascetic	3.39	Ascetic	3.38
	4		Total ATPA	4.02	Total ATPA	3.95	Total ATPA	3.98

needed by the subject face down on each desk. Again, in this paper-and-pencil assessment condition, subjects were denied the opportunity to compare attitudinal responses.

PROCEDURE

The motivational data were collected during New Student Week at the University of Oregon using the Marlowe-Crowne Social Desirability Scale. From the initial testing, the top and bottom 25 percent were identified as the extreme groups: subjects with high need for approval and those with low need for approval. The ATPA Inventory was administered to those subjects randomly assigned to the two neutral assessment conditions, approval-dependent and approval-independent, in group sessions during the fourth week of the term. The ATPA Inventory was administered a second time to those subjects randomly assigned to the two experimental assessment conditions, approval-dependent and approval-independent, in group sessions during the eighth week of the term. Individual appointments were made for those subjects unable to attend group sessions. In using the individual data collection method, every attempt was made to duplicate the attitude-assessment condition to which the subject originally had been assigned. Data were collected on all subjects in the neutral condition prior to the second administration of the ATPA Inventory.

RESULTS

The results of the analyses of variance revealed no significant differences for any of the main effects or interactions. These results were found for each of the five subdomains assessed and for the total ATPA Inventory. No significant differences were found in the attitudes expressed by subjects with high need for approval and those with low need for approval. No significant interactive effects were obtained between the level of approval motive and attitude-assessment conditions. No significant difference in the expression of attitudes was found for subjects in either attitude-assessment conditions, the neutral or the experimental. Individual and group methods of collecting data had no significant effect upon the attitudinal responses of the subjects in this study. Descriptive data appear in Table 2.

Table 2. Means and Standard Deviations Representing Attitude Toward Physical Activity Subdomains for Extreme Groups

Subdomains	No. of Items	High Need			Low Need		
		N	M	SD	N	M	SD
1. Social	8	97	31.77	± 7.2	99	29.94	± 6.3
2. Health/Fitness	11		45.25	± 9.7		43.30	± 9.6
3. Vertigo	9		39.98	± 8.0		40.61	± 8.4
4. Aesthetic	9		40.09	± 9.7		37.87	± 9.8
5. Ascetic	8		29.22	± 8.1		27.06	± 7.6

For each of the subdomains, the direction and intensity of the attitudes expressed by the subjects with high need for approval and those with low need for approval are shown in Table 1. Using the per-item mean of 4, each subdomain was compared to this value to determine its positive or negative direction and the intensity of this direction. With a range of 1 through 7, values above 4 represent a positive attitude and those below 4 represent a negative attitude. Slightly positive attitudes were expressed by subjects at both extremes for the subdomains of vertigo and aesthetic experience, while slightly negative attitudes were expressed toward physical activity as a social experience and as an ascetic experience. In general, most means hovered around neutral.

A comparison of the order in which high-need and low-need subjects ranked the five subdomains is also presented in Table 1. The rankings given the subdomains by the high- and low-need subjects are quite similar. The subdomains given the highest rankings and representing the most positive attitudes were physical activity perceived as the pursuit of vertigo and as an esthetic experience. Physical activity as health and fitness, a social experience, and as an ascetic experience were ranked third, fourth, and fifth, respectively.

DISCUSSION

The purpose of this study was to determine if attitudes toward physical activity as expressed by college freshman women were affected by the motivational variable of the need for approval. It was proposed that this underlying psychological state would function in a manner that would change the direction and intensity of those attitudes expressed. A second question was asked: Once the initial strength of this motive has been determined, could it be experimentally aroused to produce additional fluctuations in the attitudes expressed by subjects with high need for approval? It was expected that attitude scores of subjects with low need for approval would not fluctuate.

The results did not support the hypothesis that women with high need for approval would differ from women with low need for approval in attitudes toward physical activity perceived as social experience, health and fitness, pursuit of vertigo, esthetic experience, and ascetic experience. Based upon the need to present a socially desirable image, it was assumed that attitude items related to the subdomains of physical activity perceived as a social experience and as an esthetic experience would elicit strong positive attitudes from approval-dependent subjects. Previous studies have found these subdomains, without exception, to be highly valued by females (Alderman 1970; Delaplane 1969; Kenyon 1968; Mullins 1969; Zaichkowsky 1975). Physical activity perceived as the pursuit of vertigo and as an ascetic experience should have elicited negative responses from the approval-dependent subjects. Highly competitive sports and vertigo-type activities have been found to be exclusively male-oriented domains (Alderman 1970; Delaplane 1969; Kenyon 1968; Mullins 1969; Zaichkowsky 1975).

It was expected that females with low need for approval would view the five subdomains from a different perspective. Their responses should have been to personal demands other than the need to present a socially desirable public image.

It appears that the approval motive was operative at a very low level, if at all, in this investigation. Similar results were reported by Kenyon (1968). It should be noted that the means of the high-need subjects were slightly higher than the means of the low-need subjects for all subdomains with the exception of the vertigo domain.

Some of the error variance may be attributed to the generalized nature of specific ATPA Inventory statements. Lacking personal relevance, some items may have failed to elicit the desired responses. It is possible that items not including the personal pronoun "I" failed to elicit maximum intensity of feeling from the subjects. However, it seems doubtful that the direction of the responses, positive or negative, would have been changed.

Assuming that high-need subjects are more cautious in their behavior (Barthel 1964), or that they could not judge the correct social-desirability position on a given item scale, we might have expected that they would have responded close to the scale midpoint, a safe neutral position. The size of the standard deviations reported in Table 2 shows that this phenomenon did not occur.

If the experimenter were perceived as a dispenser of social approval and identified with positive attitudes toward physical activity, high-need subjects should have responded with more positive attitudes than low-need subjects. This could have been interpreted as conforming behavior designed to solicit approval by being a "good" subject in this particular study. Again, it appears that this phenomenon did not occur.

Being first term freshmen, many of the subjects from both extreme groups were enrolled in a large variety of required physical education classes. Thinking that their physical education teacher might see their attitudinal responses could have affected the responses of the high-need subjects. However, if this had been a strong motivating factor, it seems logical that the attitudes expressed by these subjects would have been considerably more positive than they actually were. As can be seen in Table 1, the intensity of the positive attitudes held by the high-need subjects was not high. Low-need subjects would not be expected to yield to social pressures from the experimenter or teacher. Consequently, their attitudes should not have been expected to reflect these pressures.

The results of this study did not support the hypothesis that there would be interactive effects between attitude-assessment conditions and level of approval motive.

Based upon the findings that indicate increase in conformity to group expectations when the subject knows that her judgments can be identified (Cohen 1964) and when she knows the consequences of her actions (Crowne & Marlowe 1964), it was assumed that in the experimental attitude-assessment condition the personal attitudes of the high-need subject would be suppressed or masked in favor of presenting a public image appropriate to her subculture — the college population. Because she possesses a motivational pattern that minimizes the need for approval, it was expected that the low-need subject would be unaffected by the instructional set used in this condition.

Once again, it appears that the approval motive was operative at a low level, if at all, in the experimental condition. It should be noted that in all but one subdomain the high-need means changed across attitude-assessment conditions in a consistent direction — toward a more positive attitude in the experimental condition.

We might add that it has been shown that attempts to change personally relevant attitudes in the direction advocated by a communicator may produce shifts in the opposite direction. This phenomenon has been called the "boomerang effect." (Hovland et al. 1957). With the approval motive inoperative, it seems reasonable that some subjects from both extreme groups may have interpreted the instructional set as an unreasonable attempt to persuade them toward a positive attitudinal position, thus producing a shift in the opposite direction.

As can be seen in Table 1, subjects at both extremes reflected more similarities than differences in ranking the various subdomains. Subjects in both extreme groups possessed positive attitudes toward the pursuit of vertigo subdomain which was accompanied by a high ranking. This finding can be interpreted as reflecting the past and present opportunities for young women to engage in a variety of vertigo activities within the geographical area of the Pacific Northwest.

The most startling finding was the ranking of the social experience subdomain as fourth by both extreme groups. This ranking was accompanied by a relatively neutral attitude. In the light of previous investigations (Alderman 1970; Delaplane 1969; Kenyon 1968; Mullins 1969; Zaichkowsky 1975) in which the social experience subdomain consistently has received a high ranking by female subjects, this finding appears to be highly incompatible with the characterization of the female with high need for social approval.

We might project that a double classification system, using the scores on the Marlowe-Crowne Social Desirability Scale as an index of an individual's preference for social approval reinforcement plus an index of that individual's expectancy of success in obtaining approval satisfactions through involvement in physical activity, would have greater predictive utility in an attitude assessment study. Using this refinement, high-need females who have had approval satisfactions by direct or vicarious involvement in physical activities might be expected to hold positive attitudes while high-need subjects who have received minimal social approval in physical activity situations might be expected to reflect negative attitudes.

Assuming that involvement with or participation in physical activity is socially undesirable for females in our society, it might be expected that women designated as high in the need for social approval would express negative attitudes toward all the subdomains of physical activity represented in Kenyon's ATPA Inventory.

In terms of a motivational approach to understanding physical activity, it appears that for women in this study, the need for social approval was not a major determinant of direction and intensity of "feeling" about various

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kinds of physical activities. In terms of subcultural norms, perhaps physical activity is one sociopsychological dimension that holds a strong neutral position; or, perhaps it lies outside the boundaries of social approval for college-age women!

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ASSESSMENT OF MOTOR PERFORMANCE OF GIRLS AND WOMEN

The remaining articles consist of papers presented at the NAGWS-RC Research Symposium held prior to the AAHPER Convention in March 1976. The purposes of this symposium were to present and discuss methods for physiological, biomechanical, and psychosociological performance assessment of girls and women in sport.

Why do we need to assess performance? Today there are a greater number of girls and women participating more frequently in sports activities than ever before. Very little research has been conducted concerning the "new female athlete." Answers to questions concerning safety, benefits, future directions, and the dispelling of myths can be accomplished best through research — specifically, performance assessment.

Who can do it? How does one do it? Teachers and coaches can help motivate subjects to be assessed, can identify what the needs are, and can assist with assessment. Some teachers and coaches are, or can be, trained to collect data at their own site. The researcher and teacher/coach must work cooperatively so that results of the assessment can be shared with the teacher, coach, and athlete and practical application made for the benefit of the athlete. A communication network is being established to aid in multigeographic and longitudinal investigations and to facilitate the standardization of assessment techniques.

Please contact the NAGWS Research Committee Chairperson, Sharon Plowman, Northern Illinois University, DeKalb, for further details.

BODY COMPOSITION ANALYSIS BY BODY DENSITOMETRY

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Over the last decade, the use of body composition analysis has become increasingly common as part of the overall physiological evaluation of athletes, for several reasons. Excessive weight, if it is fat, acts as a burden during performance. There is concern about whether weight increases and decreases are caused by changes in fat or in muscle mass. The effects of extreme weight cutting is also a concern.

Body densitometry is the method of analysis most commonly used in exercise physiology laboratories. The purpose of this report is to describe its procedures and underlying theory. In addition, the limitations of the procedure relative to its underlying assumptions and possible error in the interpretation of results are discussed.

TERMINOLOGY AND CONCEPTS

The purpose of body composition analysis is to divide the body into defined parts. There are various possibilities, such as identification of specific organ systems, cell types, or fluid compartments. The usual concern, however, is to identify the fat and nonfat components of body structure.

Body composition work has, like other fields of research, developed a terminology with which the potential investigator should be familiar. Some of the more important terms are defined as follows:

Depot or storage fat is fat stored in the adipose cells of the body as a nutritional reserve.

Essential fat is fat that is necessary for normal physiological function. It includes lipid substances normally found in such places as cell membranes and surrounding nerve fibers, as well as fatty tissue that is normally part of specific organs.

Lean Body Mass (LBM) is a concept of Behnke (1961) and refers to all of the body tissue except depot fat, including essential fat.

Fat-Free Mass refers to all of the body tissue except fat (Keys & Brozek 1953). It does not include the essential fats. The fat-free mass would be less than the lean body mass.

Lean Body Weight (LBW) is the quantitative expression of the LBM, usually expressed in kilograms.

THEORY UNDERLYING BODY DENSITOMETRY

There are many procedures available for measuring body composition. Some of these are used primarily for research, while others are appropriate for field testing, such as in physical fitness classes, the athletic training room, or on large populations.

Common field techniques involve the use of anthropometric measures to estimate either LBW or fat content. Measures commonly used are body circumferences, skeletal dimensions, and skinfolds. The estimate is made by the use of regression equations, which are derived in studies in which the more sophisticated methods of body composition analysis are employed to validate the equations.

There are three methods of analysis commonly used in body composition research. These are hydrometry, ^{40}K analysis, and body densitometry. Hydrometry involves the measurement of total body water. Since there is an inverse relationship between body water content and fat, this procedure can give a good estimate of fat content. Measurement of body water usually requires the injection of tracer substances into the blood and, as a consequence, is a medical procedure that usually is not practical for testing athletes.

The isotope of potassium, ^{40}K, occurs naturally and is taken into the lean tissues of the body like other potassium. The ^{40}K content of the body can be measured by the use of equipment that counts radioactive emissions, and the amount is then used to estimate the LBW on the basis of knowledge about the average grams of potassium per kilogram of lean tissue. The equipment for this procedure of assessment is expensive and nonportable. The procedure must be used within a laboratory.

Body densitometry is the method of body composition analysis most frequently used in exercise physiology because it is relatively inexpensive and adaptable to many research settings. The underlying concepts and procedures are presented here, but someone starting research using the techniques should review in detail articles dealing specifically with them (Behnke 1961; Behnke & Wilmore 1974; Keys & Brozek 1953; also see annotated bibliography).

Density (D) is merely the weight (M) per unit of volume (V) as expressed in the following equation:

$$1.\ D\ (g/ml) = M\ (g)\ /\ V\ (ml).$$

Density is used in body composition analysis to estimate the proportionate contributions of fat and LBM to the total body mass.

The concepts underlying the computation of fat content have been described by Keys and Brozek (1953). The basic premise is that when a system is composed of two substances of different density, the density of the whole system can be determined from the proportional contributions of the two substances, in this case fat and LBM, as expressed in the following equation (Keys & Brozek 1953):

$$2.\ D = \frac{A + B}{(A/a) + (B/b)},$$

where:

A = Proportionate contribution of component A
B = Proportionate contribution of component B
a = density of A
b = density of B
D = Body density.

The proportional contribution of either of the two components can be solved if the densities of A and B are known. Assume that B is the proportionate contribution of fat and A that of the LBM. By setting A = 1 − B and simplifying, the following equation is obtained (symbols same as in equation 2):

$$3.\ B = \frac{1}{D} \times \frac{ab}{(a-b)} - \frac{b}{a-b}$$

By making various assumptions about the densities of fat and LBM, different equations have been derived. The following serve as examples:

Rathbun and Pace (1954):

$$\%\ \text{Fat} = (5.548/sg - 5.044) \times 100$$

Brozek et al. (1963):

$$\%\ \text{Fat} = (4.570/D - 4.142) \times 100$$

Siri (1961):

$$\%\ \text{Fat} = (4.950/D - 4.500) \times 100.$$

If the body density is known, the relative fat content of the body can be measured. Each equation depends on certain assumptions. For example, the equation of Brozek and co-workers, which is commonly used, assumes that the density of the LBM = 1.100 g/ml, the density of fat is 0.9007 g/ml, and the density of the reference body (male and of average fat content) is 1.064 g/ml, which is equivalent to 15.3 percent fat (Brozek et al. 1963).

There are potential problems in applying any of these equations. First, they apply only when there is a static weight. Weight changes complicate the problem in that tissue changes during weight loss are different from tissue changes during weight gains, and special equations must be used for such conditions (Brozek et al. 1963).

Another problem is the validity of the assumptions used to formulate the equation relative to the person being tested. For example, if bone density is extremely high, as in some athletes, the true density of the LBM will be higher than the value assumed for the derivation of the equation and fat content will be underestimated. It has been shown by Weredein and Kyle (1960) that osteoporosis, which is common in older subjects, causes a decrease in bone density and an underestimation of body fat by standard equations.

The equations also make no allowance for racial or sexual differences. The equations that we use are based on data derived from males. Behnke and Wilmore (1974) note that women may have sex-specific "essential" fat in mammary and other tissues and suggest that we should use a "minimal" weight, rather than a LBW, for reference in females.

In summary, we must realize that we are dealing with *estimates* of fat and LBM with body densitometry, as well as with all of the other body composition procedures. This fact in itself does not make the procedures invalid as long as we recognize these limitations when analyzing and interpreting the data.

METHODS OF DENSITOMETRY

It has already been noted that density is the weight per unit of volume (Equation 1). It is relatively easy to measure the weight; all that is needed is a good scale. The major problem is the measurement of volume. Two approaches are generally used — volume displacement method and underwater weighing.

With the volume displacement method, a subject is immersed in water in a volumeter. The displacement of the water is measured as the subject is immersed, usually by a burette located at the side of the volumeter. The accuracy of the method is dependent on the cross-sectional area of the tank — the larger the tank, the greater the potential error.

Results from volume displacement and underwater weighing are comparable. One of the major problems with volume displacement is the need to transport a large tank to different sites. The underwater weighing procedure is felt to be more convenient and adaptable to a wide range of experimental conditions.

Underwater weighing is based on Archimedes Principle: a body immersed in a fluid is buoyed by a force equal to the weight of the displaced fluid. The following is an example:

Weight dry	60,000 g
Weight immersed	− 3,000 g
Supporting force	57,000 g

An object also is known to displace its own volume when immersed in a fluid; therefore, the volume of water displaced is equal to the volume of the subject. We also know that the density of water is about 1 g/ml, depending upon its temperature. Therefore, the volume of the subject can be determined as follows:

$$\text{Subject volume} = \text{M 9g D water (g/ml)}$$

or (for our example)

$$\begin{aligned}\text{Subject volume} &= 57{,}000\text{ g} \times 1\text{ ml/g}\\ &= 57{,}000\text{ ml.}\end{aligned}$$

A problem common to both methods is the amount of air in the lungs, which takes up space but is not part of the body volume. Therefore, the lung volume at the time of volume measurement must be measured and subtracted from the total body volume before D_B is computed. Procedures for doing this are discussed in the following section.

UNDERWATER WEIGHING PROCEDURES

Underwater weighing apparatus is usually unique to the laboratory in which it is used. The procedures described here are essentially those followed in the author's laboratory. Anyone planning to do underwater weighing should do a careful review of the literature in order to find the most desirable arrangement for his or her situation. Important books and articles are listed in the annotated bibliography included with this report.

Scales

The accuracy of body densitometry measurement by underwater weighing depends upon having quality weighing apparatus of adequate sensitivity. When using the equation of Brozek et al. (1963) to compute relative fat (% Fat = (4.570/D − 4.142) x 100), the density affects the computation to the extent that 0.001 g/ml causes a change of 0.3 percent in relative fat content. It has been our experience that same-day repeated measures can be made to an accuracy of ± 0.001 g/ml. The following recommendations are made relative to those observations:

1. Dry weight must be obtained to a minimum accuracy of 50 grams.
2. Underwater weight must also be obtained to an accuracy of ± 50 grams. A minimum sensitivity of ± 25 grams is suggested because of the problem of scale fluctuation when measuring the underwater weight. An autopsy scale has the needed accuracy (use a 9 kg x 10 g ura, 15 kg x 25 g scale). It is helpful to have the scale mechanically dampened at the time of purchase to reduce needle fluctuation during underwater weighing.
3. Calibration weights can be purchased from any scale dealer. Obtain at least one large weight (50 lb. or 25kg.) to calibrate the scale used for dry weight. First set the scale according to this dry weight; then use the scale to find the *exact* weight of several other heavy objects that are lighter than the calibration weight (e.g., 25-lb. barbell weights). Use those weights to check the calibration at higher weights. A set of weights should be purchased to calibrate the underwater weighing scale in 1 kg increments (1, 2, 3, 5 kg).

Underwater Weighing Site

Suitable equipment is anything that holds water. Plastic barrels, wine casks, stock tanks, swimming pools, and specially constructed tanks have all been reported in the literature. There are, however, some considerations that are common to all methods:

1. *Sanitation.* A small tank of water used for underwater weighing soon becomes contaminated by hair, sputum, skin oils, and cosmetics. One advantage to using a swimming pool is that this problem is

already solved. The following is suggested if a small tank is used in a laboratory:

   a. Purchase a small filter system designed for a home pool, which will not only keep the pool clean but also can be used to vacuum sediment from the bottom of the pool.
   b. A skimmer is needed to clear the surface of hair, skin oils, and sputum between subjects. A large food strainer or gauze stretched over a wire frame works very well.
   c. Home-pool chlorination (liquid) and pH control kits can be used to maintain clean water.

2. *Water temperature.* Water temperature should be maintained near body temperature (34-38°C is satisfactory), which is most easily done by locating the tank where large quantities of hot water are available. A thermometer should always be available to check the water temperature with each weighing. Use an armored thermometer, or one encased in wood, to prevent breakage and glass in the pool.
3. *Water movement.* Water movement is not a problem in a small tank (but the filter pump may need to be switched off). If measurements must be made in a pool, it may be necessary to erect a barrier around the underwater weighing site. Use the shallow end of the pool (4½ feet of water or even less is enough; water that is too deep makes subjects unnecessarily apprehensive, especially those who cannot swim).

Subject Attire

Weight belt. A weight belt of 1 to 2 kilograms may be used to sink and stabilize the subject. Less scale fluctuation is encountered if the weight is nearly aligned with the body center of gravity during underwater weighing. Have an extra weight to attach when obese subjects are weighed.

Swimsuit. It is helpful to have a standard suit style for the subjects, to reduce the problem of the effect of variation in suit weight on the computed body densities. A two-piece suit is preferable for women, because one-piece suits tend to trap air inside them. A two-piece suit also facilitates taking anthropometric measurements.

Suspension Apparatus

Use imagination. Whatever is used, the subject should feel stable and comfortable during the underwater weighing procedure. We have found that a child's swing seat suspended from a metal or wooden bar, which in turn is attached to the scale, works very well.

Residual Volume Measurement

Accurate measurement of the residual lung volume is crucial for computing the body density accurately, and the necessary equipment is usually the most expensive part of the underwater weighing apparatus. Any of a number of accepted procedures is adequate, as long as the measurement is done accurately. Procedures commonly used include the N_2 washout procedure described by Wilmore (1969) or the helium dilution method. (For discussion of the theory of both of these methods, see Comroe et al., *The Lung*, 2nd ed., Year Book Medical Publishers, Inc., Chicago, Ill., 1962). Measurement of the residual volume is done in one of three ways:

1. The residual volume may be measured while the subject is outside the water. The subject assumes a position similar to that taken when weighed under water, and the residual volume is measured.
2. The subject is weighed under water and the residual volume is measured either before or after weighing while the subject remains in the water.
3. The equipment is arranged to permit measuring the residual volume at the same time as the underwater weight is taken.

The choice of methods is affected by the available apparatus and the required accuracy. Measuring the residual volume outside the water (number 1) is the simplest method but presents two problems. First, it must be assumed that the residual volume measured outside the tank is the one attained during underwater weighing. Second, there is a slight compression of the thoracic volume while under water, which reduces the residual volume slightly. Taking the measurement while the subject is in the water with the head out (number 2) is supposed to compensate for this, but since the subject cannot duplicate the position assumed during underwater weighing, there is probably little advantage. Measurement while the subject is being weighed is most accurate but also most time consuming.

We measure the residual volume outside the tank (number 1) for research in which we survey large numbers of subjects. We have the subject try to duplicate the position taken during residual volume measurement while under water. We try to use the mean of two measures, within ± 50 ml, for computing density. In training studies, where we need a very precise duplication of results, we measure the residual lung volume at the time the underwater weight is measured.

PROCEDURES

The procedures described here are adapted from those of Katch et al. (1967). In a slightly modified form, they have also been used for measuring body composition in simple experiments designed for undergraduate students (Sinning, 1975).

Subject Preparation

It is best to do the underwater weighing early in the morning before subjects have eaten and while hydration is fairly normal. When this is not possible, subjects are advised not to eat or participate in strenuous exercise during the four hours prior to reporting to the lab. We also try to avoid measuring women during the three to four premenstrual days when they tend to retain water. Subjects should also be warned that the measurement cannot be taken if they have any serious skin infections.

Laboratory Procedures

The following is a step-by-step review of the procedures we followed during underwater weighing when residual volume is measured outside the tank.

1. The subject reports to the laboratory. If a standard suit is not used, the subject's suit is weighed before the subject dresses in it.
2. The subject is instructed to put on the swimsuit after urinating and expelling, as much as possible, any gas or feces from the bowels.
3. The residual volume and dry weight are taken. Any other anthropometric measurements should be completed before underwater weighing.
4. The subject next showers, thoroughly using soap, being especially thorough in the hairy areas of the body. It is not necessary to soap the head, but it must be thoroughly soaked. Be sure swimming gear is soaked inside and out. This step is especially important if a small tank is being used, because it removes dead skin, hair, and body oils that clutter the pool surface. It also facilitates the removal of air bubbles from the suit material and from inside the suit.
5. After showering, the subject should not dry, although it is permissible to remove excessive quantities of water that may be uncomfortable.
6. The weight belt is attached to the subject who then enters the pool and assumes a standing position. Several steps are taken to minimize the possibility of having air bubbles trapped on the body:
   a. The swim suit is pulled away from the body to allow water to enter and replace trapped air.
   b. The hands are run over the body under the suit where there is a chance of air being trapped, especially in the groin area.
   c. The head is immersed and the hair thoroughly saturated by massaging it with the fingers. Rubber bands should be available to tie up long hair if it tends to float to the surface.
   d. The hands are run over all of the exposed areas of the body.
7. The underwater weighing procedure is practiced next. One or two deep breaths are first taken before the subject sits down on the seat and becomes suspended in the tank. As the subject sits down, air is forcefully expelled from the lungs to the end expiratory position (as in the residual volume test). The breath must be held at this point. The subject should stay submerged as long as possible; it is helpful to have the subject *try* to count slowly before standing.
8. The procedure in step 7 is repeated, and the scale is read. There will be considerable fluctuation in the scale reading, but this will tend to stabilize within a relatively narrow range the longer the subject remains suspended. The scale may be hand-dampened to counteract the major fluctuations as the subject sits down, but *it must hang free when the weight is recorded.* Record the *midpoint* of the range of fluctuation.
9. Repeat the weighing procedure 10 times. After the last weighing, determine the *tare weight* — the weight of all the equipment suspended in the water. Have the subject remove the weight belt and hang the weights on the suspension apparatus, preferably at about

the same depth in the water as they were during underwater weighing. If a small tank rather than a swimming pool is used, the subject again submerges beside the swing without touching it. This action raises the water to the same level as it was during weighing. Next, read the weight on the scale. If the subject is not wearing a standard suit, it may also be weighed under water (some women's suits may have a negative weight under water).

10. Select the underwater weight(s) that meet(s) the criteria established. Different investigators have used different approaches:
    a. Katch (1968) suggests that the mean of the eighth, ninth, and tenth trials gives an accurate approximation of the "true" underwater weight. This suggestion is based on data Katch obtained through serial measurements and regression analyses of the data.
    b. Behnke and Wilmore (1974) take at least 10 determinations per subject, as does Katch. They do not use his recommendation for selecting true underwater weight, because of the possibility of underestimating the actual value on a subject who attained the highest values during the first five to seven trials. They use the following criteria:
        (1) The highest obtained weight if observed more than twice.
        (2) The second highest weight, if it is observed more than once and the first criterion is not attained.
        (3) The third highest weight, if neither the first nor the second criterion is attained.
    c. In our laboratory we have the same criteria as Wilmore and Behnke. Our approach has been to use 10 trials and then select the mean of the three highest weights within ± 50 grams, since this is within the limits of the accuracy of the procedure.

COMPUTATIONS

Use the following computations to find the LBW from the underwater weighing data:

1. Find the body density in g/ml according to the equation of Goldman and Buskirk (1961):

$$DB = \frac{Ma}{\frac{Ma - Mw}{Dw} - RV},$$

where:

Ma: Weight of subject in g
Mw: Underwater weight in g
Dw: Density of water at temperature taken during underwater weighing (see Appendix A for table of values)
RV: Residual volume in ml.

2. Compute the relative fat (% Fat) according to the equation of Brozek et al. (1963):

$$\% \text{ Fat} = \frac{4.570}{D_B} - 4.142 \times 100.$$

3. Compute the absolute fat (i.e., the total weight of the stored body fat) according to the question:

$$\text{Fat} = \text{Weight} \times \frac{\% \text{ Fat}}{100}$$

Fat and weight in Kg.

4. Find the LBW:

$$\text{LBW} = \text{Weight} - \text{Fat}$$

Fat, LBW, and Weight in Kg.

COMMENTS AND SUGGESTIONS

After several years of working with these procedures, we have noted some things that may be of practical value for those just starting.

1. When new laboratory assistants are learning the procedures, we practice independent readings by working with a trained technician. Each trainee records an estimated weight, and after five or ten trials group members compare notes. It is only a short time before everyone is reading the scale within a range of 10 to 20 grams, well within the accuracy of the method. This is a good way to check staff competency from time to time.
2. Subjects will vary in their reactions to underwater weighing. Subjects who have a fear of water or a tendency toward claustrophobia may become quite tense, causing excessive scale fluctuation. It has been our experience that the only thing the tester can do is have patience; more than 10 trials may be needed. Do not worry if the subject deviates from instructions, as long as the subject evacuates as much air as possible from his or her lungs, achieves scale stability, is not touching the bottom or sides of the weighing tank, and is firmly attached to the suspension apparatus.
3. Anthropometric measurements should be taken before underwater weighing. The warm water produces hyperemia, which causes the skin to swell slightly. It also is difficult to do the anthropometric instruments on wet skin.
4. Do not fill a small tank just before using it. Small bubbles form, causing the density of the water to be different from the value expected according to its temperature. Fill the tank one day before testing, so that small volumes of water will need to be changed to regulate the temperature on the day of testing. Also, if using a filter pump, set the return hose *below* the water line to reduce bubble formation.
5. Some investigators add 100 ml to the residual volume measure to allow for flatus. However, many feel that the true amount is quite variable and that this adjustment does not really add to the accuracy of the procedure. Flatus is reduced by not weighing the subjects too soon after a meal and encouraging them to use the toilet immediately before being tested. (We feel that the best time of day for testing is before breakfast.) We have never added this correction when making our computations.

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APPENDIX A
DENSITY OF WATER AT DIFFERENT TEMPERATURES (Rounded to 0.0001)

Temperature (°C)	*Dw (g/ml)*
21	0.9980
22	0.9978
23	0.9975
24	0.9973
25	0.9971
26	0.9968
27	0.9965
28	0.9963
29	0.9960
30	0.9957
31	0.9954
32	0.9951
33	0.9947
34	0.9944
35	0.9941
36	0.9937
37	0.9934
38	0.9930
39	0.9926
40	0.9922

APPENDIX B
SAMPLE DATA RECORDING FORM

Date ____________ Time ____________

Dry wt. (Avoir.) __________ lbs. ______ oz.

Dry wt. (Nude) ____________ g

Technician ____________________

453.6 gms = 1 lb. 28.3 gms = 1 oz.

Name ____________________

Weight ____________________ kg.

D_B ____________________ g/ml

Fat ____________________ %

Fat ____________________ kg

LBW ____________________ kg

V_R ____________________ cc

UNDERWATER WEIGHING

Trial	Weight (g)	Water Temp.
1	________	________ °C
2	________	Water Density
3	________	________ g/ml
4	________	
5	________	Suit Weight
6	________	Wet______ g
7	________	Dry______ g
8	________	
9	________	
10	________	
Tare	________	

Weight (2 Highest ± 50 gms)

________________ g

Under Water Wt. (wt. - Tare)

________________ g

RESIDUAL VOLUME

% N_2 (1)	______	______	______
% N_2 (2)	______	______	______
T Gas	______	______	______
BTPS	______	______	______
RV	______	______	______

. . . .

RV (2 Lowest ± 50 ml)

____

COMMENTS

ANTHROPOMETRIC MEASUREMENTS

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Anthropometry can be defined as the measurement of the size and dimensions of the human body. Many quantities are measured: height, weight, limb lengths, various circumferences, volumes, and specific gravities. Using these data, one can study the interrelationships of various parameters. The measurements are used in many areas: by engineers, in the design of equipment and appliances; by clothing manufacturers, in the sizing of clothes; by nutritionists, in studying growth and development; and by anthropologists, in studying primitive and fossil man. In biomechanics, the measurements are used in the analysis of motion, which is our primary concern. The specific quantities needed are segment or limb lengths, segment weights, position of the center of gravity for each segment, and radius of gyration for each segment. It is necessary either to measure these quantities directly or to be able to estimate them from other available measurements. Some of the measurements cannot be taken on living subjects, so a reasonably precise way of estimating them must be developed.

Borelli, in 1680, was the first to attempt to measure whole-body center of gravity. He placed the subject on a board balanced on a knife edge. In fact, he was dealing with the center of gravity of the entire system, rather than just the subject. In 1836, the Weber brothers developed a platform supported at the center of gravity. The body was moved until the board tilted, and this procedure was repeated several times from both ends, thus eliminating the weight of the board. DuBois-Reymond (1900) was the first to use the reaction board (a board with a scale at one end). When the weight of the person was known, the scale reading would vary with the distance of the center of gravity from the scale, and the distance could be calculated. Basler (1931) used a triangular board and two scales, thus determining the position of the center of gravity in relation to two planes, using only one measurement. In 1966, Santschi, DuBois, and Omoto determined the position of the center of gravity by a method primarily used for moment of inertia. The subject was strapped into a compound pendulum with known inertial properties. The pendulum was swung and the period determined. Then the process was repeated with a second, different pendulum. With this method, the measurement was made with the body in its proper relation to gravity, as opposed to the previous methods, where the displacements of flesh and viscera were orthogonal to the direction of measurement.

Determinations of whole-body center of gravity were the first performed, since they could be done with reasonable accuracy using relatively simple equipment. Although usually determined in relation to height, the center of gravity can also be determined in relation to breadth and depth. The limitation of early methods was that this determination held true only for the particular position studied. When several positions were involved, the measurements had to be repeated for each position.

In the analysis of motion, the center of gravity is usually determined by the segment method. The body is composed of segments, each with its particular weight and center of gravity. Just as the total body weight is the sum of the weights of the parts, the total-body center of gravity can be determined from the centers of gravity of the individual segments. The advantage of this method is that once the segment data are known, the center of gravity can be determined for any body position. Therefore, the accuracy of the method depends on the validity of the segment data.

In 1860, Harless dissected the cadavers of two executed criminals. He separated adjoining segments through the joint centers, weighed the segments, and determined their centers of gravity using a specially constructed balance device. Nine years later, Braune and Fischer (1869) worked on four frozen male cadavers. The total-body center of gravity was determined by suspending each cadaver from three different points. Cadavers were then divided into segments, separation being made through the joint centers. The segments were weighed and the centers of gravity determined by the suspension method. The researchers found a close correlation between joint axes and centers of gravity. For example, in the upper arm and upper leg, the center of gravity was found to be on the straight line connecting the proximal joint center in the head of the bone to the midpoint of the line passing through the center of the distal joint. They also found the center of gravity generally to be 4/9 of the total distance from the proximal joint. Fischer's study in 1906 included a determination of the radii of gyration of the individual segments.

The next major cadaver study was undertaken in 1955 by Dempster. Using eight frozen male cadavers, he determined the joint center on the basis of X-rays, then sawed through the appropriate planes. Segments were weighed, centers of gravity were determined using the balance plate, and each segment was swung in order to determine the moment of inertia. Dempster described the location of the center of gravity both as a percentage of the length of the segment and in terms of its relation to various anatomical landmarks. He also determined the specific gravity and expressed the weight as a percentage of total body weight. The limitation of Dempster's sample, aside from the fact that it was exclusively male, is that his cadavers represented individuals of the older segment of the population, being both smaller and lighter than average.

In 1957, Barter compiled the data from Dempster, Braune and Fischer, and Fischer, and subjected them to a regression analysis. Although there were no differences in dismembering techniques, Barter termed them insignificant in the light of the advantages gained by creating a larger sample. He felt that the results would provide better means of estimating segment weights.

So far, the trunk had been considered as a rigid segment. The studies of Parks (1959) concern the determination of the center of gravity of the trunk during changing positions of flexion and extension. Slicing the trunk into one-inch sections, he determined the centers of gravity for each subsegment. From these data he went on to determine a line of centers of gravity along the trunk. In the normal standing position, this line is not straight. To determine the actual center of gravity for a particular position, he used the following method. A cardboard cutout of the trunk for the particular position was prepared. The line of centers of gravity was marked, and a lead strip corresponding in size to the distribution of the trunk mass was placed along the line. The cutout was then balanced on the knife edge in order to determine the total trunk cen[illegible] of gravity.

The next major study was underta[illegible] by Clauser, McConville, and Young (1969), who posed the following questions: can the body segment parameters of weight, volume, and center of gravity be predicted from one or more anthropometric measures with the necessary accuracy? Can prediction equations for estimating weight and center of gravity for each segment provide an accurate estimate for individuals as well as populations? Fourteen male cadavers were used. Extensive measurements were made on the bodies and the whole-body centers of gravity were determined. Before the cadavers were dismembered, the planes of segmentation were checked with a fluoroscope to be sure that they coincided with the desired landmarks. The weight and centers of gravity of the segments were determined, and the data were subjected to a stepwise multiple regression analysis. The results consisted of a series of regression equations for determining weight and center of gravity from several other anthropometric measurements. Segment center of gravity was also expressed as a percentage of segment length and segment weight as a percentage of total body weight. Comparison of predicted values from the two methods showed that the regression equations did indeed provide a better estimate, both for individuals and for populations.

The immersion technique has been used on live subjects to infer segment weights from segment volumes, where the specific gravity is known from cadaver studies. Dempster (1955) used 39 male college students and expressed the volumes as percentages of total body volume. He then calculated the segment centers of gravity and from those data predicted the total-body center of gravity. When the predictions were compared to a direct measurement, the differences were found to be very small.

Cleaveland (1955) assumed a uniform density for each segment and found the center of gravity by the water displacement method. He assumed the center of gravity to be at the point where half the volume of water was displaced, calling this a center of volume. Clauser and others (1969) concluded that this center of volume approximated the center of gravity as proximal to its true location and determined the percentage of volume displaced that would represent the true location of the center of gravity.

Drillis and Contini (1966) determined the volume, mass, specific gravity, moment of inertia, and center of gravity in living humans. They used a segment zone method, where water was added in stages to the tank and

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the distribution of volume determined throughout the length of the segment.

It is also possible to determine segment weights or centers of gravity using the reaction board. One of the quantities must be known or assumed in order to find the other.

Body segments can be represented as regular geometric solids and a mathematical model developed to predict the parameters. Hanavan (1964) used 25 anthropometric measurements in order to calculate segment dimensions and found the method quite adequate.

All the studies so far have one thing in common. They were performed on the male half of the population. There are considerably fewer studies using female subjects. Plagenhoef (1971) used the water displacement method to determine segment volumes of 83 women and expressed the segment weight as a percentage of the total body weight.

Bernstein (1967) found the weight and center of gravity for 152 subjects, both male and female. He found no significant differences in the distances to the centers of gravity between the males and the females. He did, however, find the significant difference in thigh volume and in the volume of the distal portions of the limbs.

In 1972, Clauser and others measured 137 different dimensions on a sample of 190 Air Force women. No limb volumes were measured. Whole-body specific gravity was determined for a subsample of 95.

Kjeldsen (1972) collected data on 12 college females. Six were physical education majors, with hip width greater than shoulder width, and six were varsity gymnasts with shoulder width greater than hip width. Shoulder width was measured as the distance between the tips of the acromion processes, and hip width was the distance between anterior superior iliac spines. The subjects were marked for plane segmentations through joint centers. The landmarks used were those of Dempster (1955) for his saw cuts. For the hip and trunk segments, three points were used to define a plane. For the elbow and knee, two were found to be sufficient. The segment lengths were measured and the volumes determined by the water displacement method. Dempster's data (1955) on specific gravities were used to determine segment weights. Segment lengths and weights were expressed as percentages of the total body height and weight. Trunk centers of gravity were also obtained, by the cardboard and lead cutout method of Parks (1959). The trunk was divided into three segments — head and neck, thorax, and abdomen — and the parts were compared to each other. The radius of gyration was obtained by swinging the cutout and measuring the period of the pendulum. Kjeldsen found that the trunk center of gravity differed between the two groups of women, but since both groups differed more from the men in Plagenhoef's study (1971) than from each other, one might therefore conclude that the body build is not of major importance in movement analysis involving the female *trunk* as a *whole* (see Table 1).

The segment lengths did not vary greatly between the groups of women, or between men and women, except for the upper arm (Table 2). Female gymnasts seem to have longer upper arms than males or female nongymnasts. Further study is needed in order to determine the prev-

Table 1. The Location of the Whole Trunk Center of Gravity

Group	*Percentage of the Total Trunk Length**
Women Gymnasts	57.71%
Women Nongymnasts	56.16%
Men (Dempster)	66.00%

*Trunk includes the head and neck.

*From: Body segment weights, limb lengths and the location of the center of gravity in college women. Unpublished master's thesis by Kirsti Kjeldsen, University of Massachusetts, 1972.

Table 2. Segment Length Percentages of Total Body Height

Segment	*Women Gymnasts*	*Women Non-gymnasts*	*Men (Dempster)*
Upper Arm	19.3	16.5	17.2
Forearm	16.6	16.2	15.7
Thigh	24.7	25.1	23.2
Shank	25.6	25.2	24.7
Hip to Shoulder	30.0	30.1	30.0

Differences

Segment	*Women-Non-G Women-G*	*Women-Non-G Men (Dempster)*	*Women-G Men (Dempster)*
Upper Arm	2.80	.70	2.10
Forearm	.40	.50	.90
Thigh	.40	1.90	1.50
Shank	.40	.50	.90
Hip to Shoulder	.10	.10	0.00

alence of this characteristic. There is a possibility of a mechanical advantage for the female gymnasts associated with the longer upper arms. However, a study (1974) comparing different groups of male gymnasts with nongymnasts showed the male gymnast to have shorter extremities in general, including upper arms.

The percentage of trunk segments to total trunk weight in Kjeldsen's study differed as expected, because of the original grouping (Table 3). Therefore, in movement analysis dealing with trunk segments, female body build must be taken into consideration.

The segment weights expressed as percentages of total body weight were also different (Table 4). Gymnasts had the smallest thighs, while the nongymnasts had the largest, with the males falling in the middle. Gymnasts' trunk weight percentages of total body weight were the largest; in nongymnasts they were the smallest; and the males were once again in the

Table 3. Percentages of Trunk Segment Weights of Total Trunk Weight

Segment	*Women Gymnasts*	*Women Non-Gymnasts*	*Men (Dempster)*
Head and Neck	15.61	14.33	17.3
Thorax	28.65	26.78	33.7
Abdomen and Pelvis	56.74	58.89	49.0

Differences

Segment	*Women-Non-G Women-G*	*Women-Non-G Men (Dempster)*	*Women-G Men (Dempster)*
Head and Neck	1.28	2.97	.69
Thorax	1.87	6.92	5.15
Abdomen and Pelvis	2.15	9.89	7.74

Table 4. Body Segment Weight Percentages of Total Body Weight

Segment	*Women Gymnasts*	*Women Non-Gymnasts*	*Men (Dempster)*
Hands	1.03	1.0	1.3
Forearms	3.21	2.9	3.8
Upper Arms	5.49	5.8	6.6
Feet	2.48	2.7	2.9
Shanks	10.98	11.0	9.0
Thighs	16.52	24.3	21.0
Whole Trunk (including head and neck)	60.24	52.3	55.4

Differences

Segment	*Women-Non-G Women-G*	*Women-Non-G Men (Dempster)*	*Women-G Men (Dempster)*
Hands	.03	.30	.27
Forearms	.41	.90	.59
Upper Arms	.31	.80	1.11
Feet	.22	.20	.42
Shanks	.02	2.00	1.98
Thighs	8.28	3.30	4.48
Whole Trunk (including head and neck)	8.06	3.10	4.84

middle. In averaging the women's data, however, these differences seem to disappear, and the average is not too far from the male data collected by Plagenhoef (1971). There seems to be a greater variability among women than men, and an effort should be made, therefore, to consider the female body type when dealing with movement analysis.

To use this information in the kinetic analysis of motion, certain basic assumptions are made:

1. That each segment is a rigid body that has a constant center of gravity and moment of inertia.
2. That human joints move in ways that can be described in terms of combinations of different types of mechanical joints, such as ball-and-socket or hinge.
3. That motion is around a fixed joint center or that the path of the joint center is known.

Usually the standard percentages from Dempster's studies are used for locations of centers of gravity, radius of gyration, and segment weight, unless we have collected specific data on the person being filmed. The segment lengths can be measured directly from the film.

Until cadaver dissections are performed on females, we must continue to use available male data for studies involving females. We must also calculate moments of inertia around the long axis from known shapes that approximate the limbs.

Because the specific gravity of females is different from that of males, it is doubtful that the specific gravities obtained from males for the various segments are in fact applicable to women. Clauser and others (1972) found an average density of 1.031 for women, with a range from 0.997 to 1.061. This range does not even include the male average of 1.0629 found by Keys and Brozek (1953). Again, a cadaver study is required to determine the specific gravities of female segments better. It could also be that specific gravities of female body segments vary according to body type, because different builds tend to store body fat in different areas. Perhaps segment specific gravities should be related to total specific gravity as well.

Further information is needed on age as well as sexual differences, since specific gravity appears to decrease with age. There are also undoubtedly developmental differences for both males and females. Data are needed on immature females especially, and longitudinal studies would supplement cadaver information.

Further study of female body types is necessary, and a classification system is needed, as well as the appropriate data for the various types. In analyzing women's sports performances, it is apparent that we are not dealing with "average" body types; we often see extremes. In gymnastics, most participants are small and light for their height, and many very young girls perform at high levels. Undoubtedly, the extreme body type confers an advantage, and it could be misleading to analyze the motion of the basis of average values or values obtained from studies conducted on males.

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MAXIMAL AEROBIC CAPACITY TESTING

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The ability to use oxygen during exercise is one of the most important determinants of success in endurance activities. Athletes who compete in long-distance running and cross-country skiing have the highest maximal oxygen uptakes recorded. Most of the data reported in the literature has been collected on male athletes. Little information is available on female athletes. McArdle et al. (1972) summarized the maximal oxygen uptake data on women athletes available in 1972. The highest group average maximal oxygen uptake reported for U.S. athletes was 51.1 cc/kg · min for two young track girls (Drinkwater & Horvath 1971). More recently, Wilmore and Brown (1974) have reported maximal oxygen uptake averaging 59.1 cc/kg · min for a group of highly trained women distance runners. This is slightly lower than the average maximal oxygen uptake of the U.S. Women's Nordic Ski Team (64.4 cc/kg · min) but higher than the 53.1 cc/kg · min observed for the U.S. Women's Alpine Ski Team (Dickinson, Haymes & Sparks 1976).

More information on highly trained women athletes is desirable. With the increased emphasis on women's athletics at the high school and college levels, more women are competing and better training programs are being used. Much of our present data on women athletes was collected prior to Title IX and may be outdated. Information is also needed on young girl athletes who begin training prior to puberty.

Maximal aerobic capacity tests are designed to measure the maximal oxygen uptake of the individual during exercise lasting more than a few seconds. Several different techniques have been devised for assessing maximal aerobic capacity. The three most commonly used techniques are the treadmill, bicycle ergometer, and bench-stepping tests. Since most laboratories equipped to measure oxygen consumption will have either a bicycle ergometer or a treadmill, bench-stepping tests will not be discussed.

EQUIPMENT

The first step in preparing to test maximal aerobic capacity is to secure the following necessary equipment:

Treadmill or bicycle ergometer
Bags for collecting expired air (Douglas or neoprene), or samples of expired air should pass directly through a dry gas meter or into a spirometer
Spirometer

Dry gas meter (optional)
Gas analyzers - oxygen and carbon dioxide
Breathing valve or mask
Mouthpieces
Nose clip
Gas tubine
Three-way valves
Heart rate monitor (electrocardiograph)
Barometer
Thermometer
Clock with second hand
Scale.

Additional supplies needed include calibration gas for calibrating the gas analyzers, electrodes, electrode paste, alcohol, and tape for monitoring the electrocardiogram.

PROCEDURES

The second step is to decide which test to use. Should the test be on a treadmill or bicycle ergometer? If on the treadmill, should the subjects walk or run? Should it be a continuous or discontinuous protocol?

Studies comparing bicycle ergometer and treadmill tests show that maximal oxygen uptake on the treadmill is 10 to 12 percent greater than on the bicycle ergometer (McArdle, Katch & Pechar 1973; Pechar et al. 1974). If both the treadmill and bicycle ergometer are available, the treadmill would be the equipment of choice except for training studies using cycling and swimming since training is specific to the muscle groups used during exercise. Greater increases in maximal oxygen uptake have been observed on the bicycle ergometer than on the treadmill among subjects training on the bicycle (Pechar et al. 1974). No increase in maximal oxygen uptake on the treadmill (Magel et al. 1975) or predicted maximal oxygen uptake on the bicycle ergometer (Fish & Haymes 1976) have been observed among swimmers following training, although the maximal oxygen uptake during swimming increased in both studies.

Treadmill tests can be either walking or running and can have either a continuous or discontinuous protocol. Four widely used methods are the Balke (Balke & Ware 1959), Bruce (Bruce, Kusmi & Hosmer 1973), Mitchell-Sproule-Chapman (1958) and Taylor (Taylor, Buskirk & Henschel 1955) protocols. Both the Balke and Bruce protocols are continuous walking tests, while the Mitchell-Sproule-Chapman and Taylor protocols are discontinuous running tests. Research shows that higher maximal oxygen uptakes are achieved during running tests (Froehlicher et al. 1974; McArdle, Katch & Pechar 1973; Stamford 1975).

Little difference has been found between continuous and discontinuous running tests (McArdle, Katch & Pechar 1973). One of the major disadvantages of walking tests is the steepness of the grade if the test is prolonged. Many subjects complain of pain in the legs and back when walking on the steeper grades. However, the continuous walking tests do have an advantage in the short period of time necessary to complete the test as opposed to the discontinuous running tests. As a compromise, a continuous running protocol is suggested as the best method of testing female athletes and girls and women who are active in jogging/running programs. For women who have not recently been involved in exercise programs, the walking treadmill protocol is recommended. The Balke and Mitchell-Sproule-Chapman protocols are described below in detail as is a continuous running protocol similar to that of Madsud and Coutts (1971).

Balke Protocol

Treadmill speed is 3.4 miles per hour (90 meters per minute). Subjects begin walking at a 0 percent grade. The grade is increased 1 percent per minute until the subject can no longer continue or the treadmill reaches an elevation of 20 percent. At the 20 percent grade the speed should be increased 0.1 miles per hour per minute until the subject can no longer continue (McArdle, Katch & Pechar 1973). Expired air collection should be started when the subject reaches a heart rate of 170 beats per minute. In older women and women unaccustomed to exercise it may be necessary to begin gas collection at a lower heart rate. Asking subjects when they think they have only two minutes of exercise left is helpful.

Mitchell-Sproule-Chapman Protocol

The subject warms up at 3 miles per hour, 10 percent grade for 10 minutes, followed by a 10-minute rest. Speed of the treadmill is 6 miles per hour for the test. The subject starts at a 2.5 percent grade for 2.5 minutes. Ten-minute rest periods are interspersed between runs. The grade is increased to 5 percent for the second run and by 2.5 percent for each subsequent run. Expired air collections are made during the final minute of each run. Subjects continue until they cannot complete a 2.5-minute run.

Continuous Running Protocol

Subjects run at 6 miles per hour beginning at a 0 percent grade for two minutes. The treadmill is elevated 2.5 percent every two minutes until the subject can no longer continue. Expired air collection should begin at a heart rate of 170 beats per minute. It is recommended that a five-minute warm-up at 6 miles per hour, 0 percent grade, followed by a five-minute rest, be used with this test.

Bicycle Test

In the event that a treadmill is not available for testing, the bicycle ergometer should be used. There is little difference between maximal oxygen uptakes using discontinuous and continuous protocols (McArdle, Katch & Pechar 1973). Since less time is needed to complete the continuous test, one used by McArdle, Katch and Pechar (1973) will be described in detail.

Pedalling frequency should be set at 60 rotations per minute using a metronome. Initially the resistance should be set at 2 kg (720 kgm), and the subject should pedal at this load for four minutes as a warm-up. The work load should be increased 0.5 kg (180 kgm) every two minutes until the

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subject can no longer continue or the pedal rate drops below 50 rotations per minute. Expired air collection should begin when the heart rate reaches 170 beats per minute.

Suggestions

Treadmill speed will need to be lower than suggested if testing young children. Running at five miles per hour is suggested for testing girls under 12 years of age. Increased treadmill speed may be desirable when testing highly trained women athletes. For example, most of the women skiers have been tested at speeds of seven to eight miles per hour. It may be necessary to lower the work load on the bicycle ergometer to 1 kg (360 kgm) for older women and women who have not been active in exercise programs.

Heart rate should be monitored throughout a maximal oxygen uptake test. Recordings of the electrocardiogram should be made during the last 10 seconds of every minute of exercise. It is desirable to have visual monitoring of the electrocardiogram throughout the test, especially when testing women over 30 years of age. The negative electrode should be securely fixed to the skin directly over the manubrium, and the positive electrode should be placed in either the V_4 or V_5 position on the chest.

If information on ventilation volume as well as oxygen uptake is desired, the breathing valve used should be carefully chosen. Several breathing valves are available. Resistance to air flow and dead space are important considerations when choosing a breathing valve. The larger valves, Triple-J (Collins) and Otis McKerrow, have a relatively large dead space which will affect ventilation volumes (Barlett, Hodgson & Kollias 1972). It would be better to use a Lloyd or Daniels valve for obtaining ventilation volumes.

Before the test begins be sure the subject has signed an informed consent statement. If the subject is a minor, it may also be necessary for her parents to sign. Record the weight of the subject, minus her shoes, in the clothing she is wearing during the test. More than one bag of expired air should be collected to be certain that the subject has reached her maximal oxygen uptake. The two bags should not differ by more than 150 cc O_2/min or 2.1 cc/kg·min. The last bag may actually be lower when maximal oxygen uptake is reached. Barometric pressure and gas temperature should be recorded at the time the gas volume is measured. Oxygen uptake volumes are corrected to standard temperature and pressure, dry (STPD), which is 0 C and 760 mm Hg, while ventilation volumes are corrected to body temperature and pressure, saturated (BTPS).

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ISOKINETIC ERGOMETRY: MEASUREMENT OF MAXIMUM FORCE AND WORK RATE CAPACITY

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During the last two decades there has been considerable research interest in the area of isometric and "isotonic" (eccentric, concentric) strength development and training programs. Studies have been conducted to evaluate different methods of training, optimal durations of training, various combinations of loads and repetitions used to improve "strength," the various biochemical and neurophysiological factors involved in exerting force under different loading conditions, and physiological changes that occur within muscle as a result of specific exercises and training programs. In 1966, a different and unique concept of exercise was introduced as an alternative to the more traditional methods of loading a muscle or group of muscles to produce maximal force (Perrine 1968). This form of exercise is referred to as *isokinetic* and is currently of interest in many disciplines dealing with human movement, especially as it relates to physical performance and sport. This report is concerned with several aspects of isokinetic exercise recently studied in our laboratory.

PRINCIPLES OF ISOKINETIC EXERCISES

Isokinetic exercise differs from both isometric and "isotonic" exercise in several ways. In a static, isometric contraction, the amount of force generated by the muscle and imparted to the resistance is accomplished with little or no external shortening of the muscle. When an object is lifted or moved by concentric or eccentric muscle contractions, the resistance provided by the object remains unchanged throughout the contraction, although the resistance is moved as the muscle shortens or lengthens during movement. Because the poorest mechanical advantage on an "isotonically" loaded muscle occurs at the extreme ranges of motion, the maximum force-generating capacity may actually be *submaximal* throughout a considerable portion of its shortening range. In contrast, the apparent limitations for loading a muscle to its maximal or absolute force-generating capacity through a *complete* range of motion are overcome with isokinetic exercise.

Sincere appreciation is extended to James Perrine for his technical expertise and suggestions regarding appropriate methodology in testing; to Lumex Inc., Bayshore, New York, for their generous support in providing equipment and assistance; and to David William K., the newest member of the team. F.I. Katch is chairman of the Department of Exercise Science.

With isokinetic exercise, a muscle encounters no resistance in an exercise movement until a predetermined speed of movement has been reached. Thereafter, resistance does develop but automatically and continuously to match effectively or accommodate the force generated by the contracting muscle at all points through the available range of motion. A mechanical device is required that can be incorporated as part of a common bench, leg, or shoulder exercise machine, bicycle, or other type of apparatus for exercising the arm(s) or leg(s). A speed-controlling mechanism in the isokinetic device operates as a governor to control precisely the speed of limb movement so that it remains constant during the time force is being generated. The lever or resistance arm begins to move when an external source exerts movement against the resistance. The external source in this case is the limbs.

The amount of force generated by the muscle is exactly matched by the isokinetic device, so that the muscle can be loaded to achieve its maximum or absolute force capacity throughout a given range of motion at the preset velocity of movement. This makes it possible to load a muscle to its maximum even at the extreme angles where there is a poor mechanical advantage. A distinction can be made in comparing an "isotonic" with an isokinetically loaded muscle. In a common weight-lifting exercise such as curling a barbell, the resistance must first be overcome, then the execution of the movement occurs. The opposite occurs in an isokinetically loaded muscle. The desired speed of movement occurs almost instantaneously, with the resistance then increasing as a function of the amount of tension that can be developed in the muscle at a specific speed of contraction.

TECHNIQUES OF ISOKINETIC MEASUREMENT

The isokinetic devices in our laboratory are equipped with electronic instrumentation so that a variety of parameters can be measured during a particular experimental procedure. Two general parameters can be measured: (a) the maximum, velocity-specific, *force capacity* at a given position, and (b) the maximum, velocity-specific, *work-rate* capacity at a given position. Both parameters can be evaluated under fatigued and nonfatigued conditions. In our experiments, we have measured both the absolute maximum force and work-rate capacity under essentially nonfatigued conditions and only in a few cases where the object was to continue performance until a so-called exhaustion point was reached.

The measurement of maximum force or work-rate capacity can be accomplished with the use of electronic integrators and computer analysis or manually by direct reading of the force tracings obtained during the measurement. A sensitive recorder can be used to obtain a permanent tracing. When a maximum force score is desired at any given velocity, we use an average of the peak force obtained during a given segment of the contraction. During a bench press movement, for example, where the arms are extended vertically while lying supine, it is possible to compute a maximum score as the peak force exerted at any point in the movement. If this occurred after 100 degrees of arm movement at some preset speed, then the maximum or "peak" force would simply be the force at that

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point. This is relatively easy to compute when the chart speed is 25 milimeters per second, as the force curve is spread out over the full range of movement. A computer can be preprogramed to compute the peak force obtained at any angle during the contraction.

In a cycling movement, where each limb exerts force during one cycle, a force tracing at a slow chart speed of 1 millimeter per second is obtained with characteristic peaks and valleys, each peak representing the maximum force generated by one limb during each half cycle. It is possible to compute a maximum force score by averaging the middle eight peaks during cycling at a preset velocity that can range as high as 150 revolutions per minute. Reliable adjacent trial and day-to-day individual differences have been obtained during three 10-second trials during cycling at 60 revolutions per minute, with a one-minue rest interval between trials (Katch et al. 1974). This result has been confirmed in subsequent unpublished experiments while pedaling at 30 revolutions per minute, and during bench press exercise performed at fast (2.1 seconds/complete movement) and slow speed (10.3 seconds/complete movement) by college women (Katch et al. 1975).

The most important consideration in testing is to give ample practice in executing the movement, as a definite "learning" curve occurs during the first few trials. We have observed that this habituation effect occurs in men and women on the bicycle, bench, and leg press apparatus, regardless of their previous "strength" training background or state of physiological conditioning. In training studies, it is crucial that sufficient practice be allowed in order to obtain a dependable baseline measurement. The exact duration of preliminary practice trials should be determined in pilot studies. There are no published data that deal with this topic, at least for isokinetic measurements.

In quantifying work-rate parameters, the following can be measured: (a) the absolute maximum work-rate at a given velocity; (b) the maximum time duration at the absolute maximum work-rate at a given velocity; (c) the *average* maximum work-rate at a given velocity; and (d) maximum power output (external work accomplished per unit time). In situations where a sustained, maximum effort is required, as in all-out cycling or repeated efforts of the bench or leg press movement performed at either fast or slow velocity, work-decrement or fatigue curves can be obtained and the area under the curve integrated to give some indication of an "endurance" score (Henry & Farmer 1949; Katch & Katch 1972).

EXPERIMENTS WITH ISOKINETIC EXERCISE

Our own interest in isokinetic exercise began in 1971 when we tried to solve a particular problem in exercise physiology. Since then we have completed six experiments, four of which are described below.

Experiment I. *The Relation Between the Maximum Force Capacity of the Legs and the Differences Between Maximal Oxygen Intake Measured on a Bicycle Ergometer and Treadmill.*

One of the factors often mentioned in trying to explain the significantly higher value of maximal oxygen intake (max $\dot{V}O_2$) obtained by treadmill (TM) compared with bicycle ergometer (BE) test procedures is individual differences in leg strength. It had been postulated that those with stronger legs should be able to perform work for longer time periods before fatigue sets in and, therefore, should have an advantage on a BE test. For those individuals, there should be a smaller difference between max $\dot{V}O_2$ measured on a BE and TM, because their BE max $\dot{V}O_2$ score should be closer to the "true" max $\dot{V}O_2$ assessed by TM procedures.

One of the problems, however, in trying to determine if some measure of leg force was related to the *differences* in TM and BE scores was the lack of a suitable methodology for measuring the absolute or maximal force-generating capacity of the legs that corresponded to pedaling a BE. It had been well established in the research literature that the application of force against resistance was specific to the method of measurement. This meant that it would be incorrect to measure force isometrically and then try to relate the isometrically measured force to a dynamic situation such as cycling. What was needed was a way of measuring the absolute force-generating capacity of leg musculature that corresponded rather precisely to the specific pattern and rate of movement in pedaling a BE. By use of a Cybex isokinetic dynamometer coupled to the pedal sprocket of a conventional Monark BE, we were able to measure and record the maximal force output of the legs while cycling at the same 60 revolutions per minute speed to measure max $\dot{V}O_2$ on the BE (Katch et al. 1974). The modified ergometer is shown in Figure 1. A large sprocket connected by a chain was attached from the dynamometer input shaft to the rear sprocket of the ergometer.

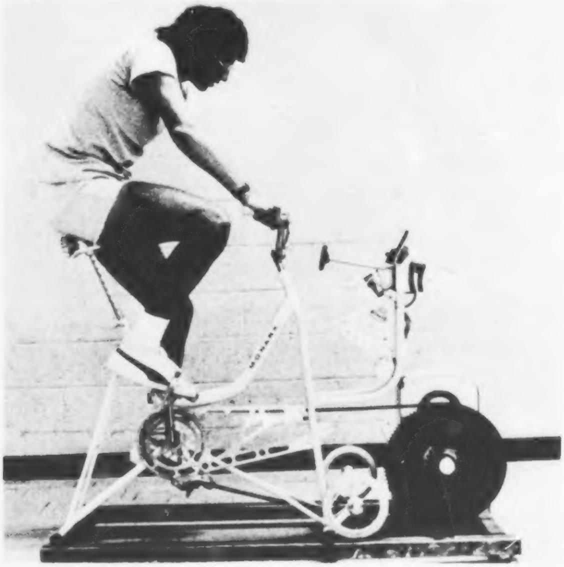

Figure 1. Subject pedaling an isokinetic bicycle ergometer. (Photo by Richard Lee.)

Maximal leg force capacity (MLFC) was assessed from the force tracings during three 10-second trials, in which the subject exerted as much force as possible while cycling at 60 revolutions per minute. In preliminary experiments it had been determined that subjects could exert maximal force for an eight- to ten-second period without decrement. A one-minute rest period was allowed between trials. The subject's body alignment and leg position on the BE was standardized and was similar to the BE max $\dot{V}O_2$ test. The middle eight peaks of each trial were averaged (four peaks each for right and left legs during the four complete cycles) to constitute a score for that trial, and the average score on all trials was considered the subject's MLFC. Careful analysis of the data on 50 college men who were tested and retested on two different days revealed the presence of considerable individual differences, as test-retest reliability ranged between r = 0.92 to 0.94 between consecutive trials on a single day and for corresponding trials across two days. Measurements also were made of leg weight by a hanging suspension method and leg volume by water displacement (leg density was calculated as leg weight/leg volume). These intercorrelations are shown in Table 1.

Table 1. Summary of Intercorrelations between MLFC and TM and BE Max $\dot{V}O_2$ and Leg Anthropometric Measurements

Variable	r
MLFC vs. max $\dot{V}O_2$ TM	.46
MLFC vs. max $\dot{V}O_2$ BE	.40
MLFC vs. Δ max $\dot{V}O_2$ TM-BE	−.13
MLFC vs. body weight	.59
MLFC vs. leg weight	.45
MLFC vs. leg volume	.47
MLFC vs. leg density	.62

for N = 50, r = .27 is significant at $P < 05$.

Δ Max $\dot{V}O_2$ TM-BE = the difference between max $\dot{V}O_2$ measured on the TM and BE, expressed in liters. Example: TM max $\dot{V}O_2$ = 4.50 liters; BE max $\dot{V}O_2$ = 3.85 liters; Δ max $\dot{V}O_2$ TM−BE = 0.65 liters.

The correlation of r = −0.13 between MLFC and Δ max $\dot{V}O_2$ TM—BE showed that MLFC during cycling, which duplicated the exact leg pattern and movement during a BE max $\dot{V}O_2$ test, did not account for the differences observed between max $\dot{V}O_2$ measured on the TM and BE. It remains to be determined whether MLFC measured under fatiguing conditions will help to explain the apparent Δ max $\dot{V}O_2$ TM—BE differences. As a point of interest, correlations also were computed between the total amount of work done on the TM and BE test and MLFC. Total work on the BE and TM max $\dot{V}O_2$ tests correlated r = 0.29 and r = −0.03, respectively, showing that it was impossible to predict how much work an individual could perform on a TM or BE test for max $\dot{V}O_2$ on the basis of nonfatigued MLFC of the leg muscalature.

Experiment 2. *Effects of Two Modes of Physiological Training on the Maximal Force Capacity of the Legs.*

This experiment was concerned with the specificity of the cardiovascular response to specific modes of training — in particular, how TM and BE training effected MLFC. Thirty-two subjects were randomly placed into a BE or TM training group. Fourteen additional subjects were recruited as controls and did not participate in any form of training. Prior to training, each subject was tested on two consecutive days for MLFC using the same procedure described in Experiment I. The subject was given three eight-second trials pedaling the BE isokinetic ergometer. MLFC was computed as the average of the middle eight peaks on the six trials for the two days. The experimental groups trained three days per week, approximately 20 minutes per day, for 10 weeks. The training regimen was as follows:

Each of the experimental subjects exercised at a heart rate of 80 percent of maximum as determined on the TM or BE test for max $\dot{V}O_2$ Daily workouts were divided into four five-minute periods. For the BE and TM training groups, the first three periods were separated by a five-minute rest. Heart rate and work output were recorded at the end of each work period. As the training effect took place, the work periods were made more difficult in order to maintain the intensity of the workouts at 80 percent of maximum heart rate. The last work period was set at an intensity that corresponded to the maximum work level done by the subject on the initial $\dot{V}O_2$ test. Each subject worked until he was able to work continuously at this level for five minutes. At this point, the work level was raised to the next higher level and the subject tried to complete five minutes at this level, and so on. As a matter of interest, maximal heart rate was almost always achieved at this last workout level, which averaged 195 beats per minute. Bicycling was done at 60 revolutions per minute and treadmill speed was six miles per hour. The friction load for the BE and angle of elevation for the TM were individually established to correspond to 80 percent of maximum heart rate. At the end of the 10-week training period, the experimental and control subjects were retested for MLFC under identical conditions as compared with the initial MLFC tests. Prior to the start of the experiment, we had hypothesized that the specificity of the training effect would show that individuals who trained by cycling would increase their maximal cycling leg force to a greater extent than individuals who trained by running on a TM. Another way of stating this is "Are the effects of specific modes of training general or specific with regard to changes in MLFC?"

The results for the control group, presented in Figure 2, showed no significant changes in MLFC after the 10-week period. For the BE training group, all of the points fall to the right of the solid line as indicated in the figure, which means there was an increase in the MLFC after training. The average increase was from 188 to 200 foot-pounds of torque, which amounted to a 6 percent improvement.

The results for the treadmill training group are also presented in Figure 2. The pretraining value of MLFC was 197 foot-pounds of torque, which increased to 206 foot-pounds of torque after training. The amount of this improvement was just under 5 percent.

When the results of the MLFC scores were analyzed between the treadmill and bicycle groups using analysis of covariance statistical techniques, the following results were obtained:

1. The group that trained on the BE improved significantly in MFLC.
2. The TM training group also improved significantly in MLFC.
3. There were no significant differences in MLFC between the BE and TM training groups. In other words, the group that trained on the BE did not improve to a greater extent in MLFC compared with the TM training group.

We concluded that, with these subjects and under the conditions of our experimental procedures, the effects of a specific type of cardiovascular training program did not differ significantly in improving MLFC. In other words, improvement in MLFC did not depend on a specific mode of training.

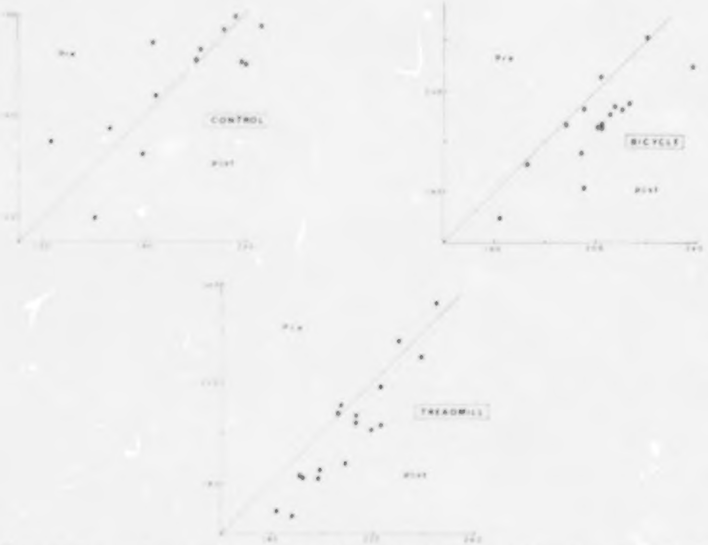

Figure 2. Pre- and post-test changes in MLFC for the control, bicycle and treadmill training groups, respectively. Score values are expressed in foot-pounds torque.

Experiment 3. *Individual Differences in Leg Force Capacity and Bicycle Endurance Performance of Women.*

This experiment evaluated the relation between individual differences in maximal leg force capacity and endurance performance of women. Twenty-nine women served as subjects. MLFC was measured on the isokinetic ergometer using the same procedures described in the two previous experiments.

Endurance performance was measured on a Monark bicycle ergometer according to the following procedures: The initial pedaling rate was 60 rpm at a friction load of 2.5 kg or 900 kg-m. The object was to try to maintain this rate of work for six minutes. Subjects who could do so without fatigue or work decrement would have 100 percent endurance. In a six-minute period, this would correspond to 5,400 kg-m of work performed. Subjects unable to maintain this rate during each minute would naturally have less total work done and would have a lower endurance score. The rationale for using this particular type of test protocol has been described in detail in previous reports (Katch & Katch 1972).

The subjects were told the test would be about five to eight minutes in length. It also was explained to them that they would not be told how much time remained in the test. This is difficult to do, but it was adhered to strictly. Each subject was tested twice for endurance performance on two days, with about one week intervening between tests.

Figure 3 summarizes the relations between MLFC and performance and body weight and performance. As shown in the insert graph, body weight was not strongly related to endurance and was not of an advantage (or disadvantage) in this type of performance. The relation between MLFC and endurance performance is shown as line AB. The correlations were highest during minutes 2 and 3 and declined thereafter.

The bottom curve is similar to the middle curve and depicts the relation between MLFC and endurance performance when the factor of body weight was statistically controlled by use of the partial correlation technique. When the factor of body weight is held statistically constant, the relation between MLFC and performance was only slightly reduced to the value shown by this curve.

The top curve (ABD) is a theoretical curve between MLFC and endurance and depicts the relation when there was no unreliability in the performance test scores. Unreliability in test scores might be caused by such factors as changes in motivation, fatigue or by bordeom. However, since this curve is also similar to the middle curve AB, which was the relation obtained between maximal leg force and performance, it can be concluded that unreliability in test scores was not a factor (it was r = 0.90 from minutes 2 to 6).

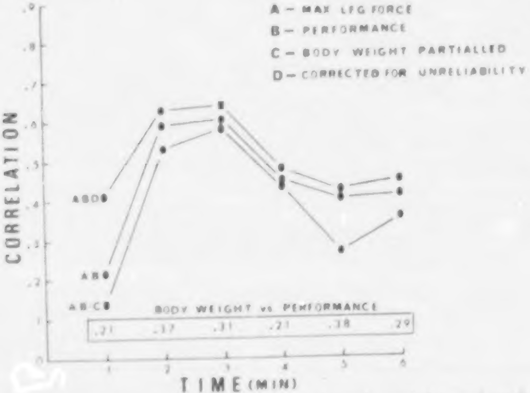

Figure 3. Relationship between MLFC and body weight and endurance performance.

What can one conclude about the results for this sample of women subjects? First, MLFC measured isokinetically during cycling under non-fatigued conditions is moderately related to an endurance performance on the bicycle ergometer. The strongest association is between MLFC and endurance during minutes 2 and 3. Second, fatigue during this endurance performance became more substantial after the first minute and increased to about 29 percent of the initial starting rate after six minutes. Third, body weight was poorly related to cycling endurance and was not an important factor in this type of performance.

Experiment 4. *Interrelations Between Isometric and Isokinetic Force Capacity, and Supramaximal Bicycle Performance of High Intensity, Short Duration.*

The last experiment concerned the interrelations between static or isometric force measured at two different angles in the joint range of motion, MLFC measured isokinetically during cycling at two speeds of movement and a supramaximal work test of very high intensity, short duration.

The subjects were 16 male undergraduate students at Queens College. Each subject was put through the various force output tests on a single day. The following measures were taken:

1. MLFC during cycling at 60 and 30 revolutions per minute on the isokinetic ergometer.
2. Maximal static force exerted by the right leg positioned at a joint angle of 90 and 140 degrees while seated on the isokinetic BE.
3. Total work output achieved during a one-minute supramaximal test involving pedaling as fast as possible against a constant frictional resistance on a Monark BE.

With the exception of the supramaximal test on the Monark BE, duplicate measurements of isokinetic and static force were made. Each of these measurments consisted of two trials. Subjects were tested in a balanced order design, with one-fourth of the subjects taking one of four testing sequences. Within each sequence, the order of administering the tests was also systematically rotated in order to balance out the possible confounding influence of such factors as learning, training, or fatigue. A one-minute rest interval was allowed between each trial for the isokinetic measurements and a 30-second rest between the static force measures. For the isokinetically measured force output at 60 revolutions per minute, the middle eight peaks were selected for analysis, and an average of the 16 peak force scores on the two trials was used to compute MLFC. For the 30 revolutions per minute measurements, a similar procedure was used, with the exception that the middle six peak scores were used to compute MLFC for each trial. A one-minute rest was allowed between trials. For the isometric measurements made at the 90- and 140-degree angles, subjects exerted maximal force for a two- to five-second period. Maximal force was the highest force recorded during this interval. An average value of the two trials was used. In the statistical analysis, average scores were used.

The procedure for the supramaximal work test was similar to that published by others in conjunction with the determination of maximal oxygen debt. Subjects were allowed one minute of preliminary practice while

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pedaling at 60 revolutions per minute against no friction load. The frictional resistance was then quickly increased to 5.5 kilograms, and the subject was instructed to pedal as fast as possible for one minute. To obtain a more detailed picture of the performance, pedal revolutions were counted by a microswitch at 10-second intervals. The subject was encouraged constantly and exorted to do his best and was informed of the time remaining after each 10-second period.

Table 2 presents the intercorrelations between the various measures of leg force capacity. As can be seen in column 2, the correlations are rather substantial and show that individuals able to exert a large amount of force under one testing condition are also able to exert a large amount of force under the three other testing conditions. This would apply to individuals who could not exert as much force. The relation between the isokinetic versus isometric force measures were a little surprising, since lower correlations were expected because of the differences in technique for measuring isokinetic and isometric force output. Even more surprising was the lack of independence between force output measured isometrically at 140 degrees and 90 degrees. Previous studies have not found this to be the case and have supported the idea of the relative specificity or independence of static force exerted by the same muscle groups but at different points in the joint range of movement.

The correlation of $r = 0.094$ between isokinetic force measured at 60 and 30 revolutions per minute also shows that decreasing the speed of movement by half did not change the relative positioning of individuals with respect to their ability to exert maximal isokinetic force at the two velocities of movement. Because body weight correlated significantly with IK 60 revolutions per minute ($r = .67$), IK 30 revolutions per minute ($r = .70$), IM 90° ($r = .65$) and IM 140° ($r = .67$), it was necessary to compute partial correlations between the two IK and IM forces scores. These partial correlations are shown in the last column of Table 2, and represent the net relation between the two variables without the possible confounding

Table 2. Interrelationship Between the Various Force Measures with the Influence of Body Weight Stabilized

Variables	$r_{1,2}$	partial correlation, weight held constant
IK 60 rpm vs. IK 30 rpm	.94	.70
IK 60 rpm vs. IM 140°	.87	.76
IK 60 rpm vs. IM 90°	.89	.80
IK 30 rpm vs. IM 140°	.85	.72
IK 30 rpm vs. 90°	.90	.81
IK 140° vs. IM 90°	.78	.58

For $N = 18$, $r = .44$ is significant at $P < .05$.
IK = Isokinetic
IM = Isometric

influence of body weight. On the average, the correlations are reduced by 16.5 percent when the factor of body weight is stabilized. However, these new values are still considered fairly moderate, and therefore, the basic conclusion still holds that individuals able to exert a large amount of force could do so regardless of the way in which the measurements were made.

Table 3 presents the descriptive data for the two isokinetic and isometric measures. The most obvious finding is that IM 140° is 2.5 to 3 times lower compared with the other three ways of measuring force. There were no significant differences between IK 60 revolutions per minute and IM 90°. On the other hand, IK 30 rpm was significantly higher compared with IK 60 revolutions per minute or IM 90°.

Table 3. Descriptive Date for the Isokinetic and Isometric Force Measurements (N = 18)

Variable	Mean	SD
IK 30 rpm	244.17	34.91
IK 60 rpm	209.26	30.56
IM 90°	211.88	63.70
IM 140°	93.35	31.81

IK = Isokinetic

Im = Isometric

Values represent mean of two trials; data are expressed in foot-lbs torque.

The data presented in Table 4 include the correlations between performance measured at each 10-second interval and the two measures of maximal isokinetic and isometric force output. The descriptive data for the 60-second supramaximal BE test are also presented for each 10-second time period. These data show that the downward trend in performance at the 60-second point averaged 56.5 percent of the initial 10-second rate. This is a large amount of work decrement, but it must be emphasized that the subjects were performing heavy work against a frictional resistance of 33 kilograms per pedal revolution. With reference to the correlational analysis, it can be observed that there is little difference in the values between the different force measures at each 10-second period. The highest values are obtained in the next-to-last column, which relates force to performance during the 50- to 60-second period. These values are equal to or slightly higher than when the cumulated minute-by-minute performance scores are used (not shown). Because the correlation between body weight and minute-by-minute or cumulative performance was low, namely $r = 0.36$ averaged for the six time periods, partialing out the influence of body weight did not change these relations to any important extent.

The present data suggest that MLFC was not appreciably related to the number of pedal revolutions turned during the first 30-second period. However, from 30 to 40 seconds, the magnitude of the correlations increased by almost twice, indicating that an individual's initial level of force capacity, measured isokinetically at 60 and 30 revolutions per minute, was

Table 4. Correlations Between Supramaximal Performance and Maximal Isokinetic and Isometric Force Output

Force measure	0-10	11-20	21-30	31-40	41-50	51-60	Total revs
IK 60 rpm	.21	.34	.41	.59	.48	.63	.61
IK 30 rpm	.24	.37	.38	.50	.45	.49	.57
IM 90°	.23	.32	.32	.44	.38	.51	.52
IM 140°	.36	.37	.28	.32	.21	.43	.49
Mean revs	17.57	16.29	13.36	10.64	8.71	7.64	74.21
Standard deviation	3.52	2.63	2.84	1.99	1.98	2.19	11.46

IK = Isokinetic; IM = Isometric
Multiply revs by 33 to convert to Kgm.

moderately and positively related to the last 30 seconds of performance. During this time period, a large amount of fatigue had occurred, and the subjects had to draw upon their leg force reserve to continue the performance.

CONCLUDING COMMENTS

Research in the area of isokinetic exercise is really in its embryonic stages. There is so much yet to learn about isokinetic exercise that it is difficult at this time to make any sweeping generalizations from the laboratory to the gymnasium or playing field. Future research will, I am sure, focus on the comparative effects of different ways of getting a muscle to achieve maximum power outputs, the optimal duration, frequency, and intensity of training, and a host of other factors that relate to training for sports.

My own view is that it will take many years of carefully conducted laboratory research before the knowledge discovered through such inquiry can be applied with any degree of certainty to the various sports and their particular training regimes. I am sure, however, that the concept of isokinetic exercise will catch on rapidly. This method of loading a muscle to achieve its maximum power output through a given range of movement at a specific contractile velocity would certainly seem to have certain advantages and direct application to various types of sports and sports training programs. I would offer a word of caution, however, in interpreting data that compares different methods of developing "strength." The question is often raised, "What method of exercise training is more effective?" Before definitive answers can be obtained, it is necessary to conduct experiments using proper controls, such as equating work-rate schedules, intensity, and duration of effort and insisting on adequate control groups, depending upon the particular experimental design. It is not possible to compare an "isotonic" barbell bench press weight lifting program with an isokinetic bench press training program without equating for total work done and/or intensity or duration of effort, or both.

My hope is that researchers around the country, including coaches and athletes, will begin to explore systematically what is a very promising and exciting area of research. The application of isokinetic exercise with ergometry provides a new perspective and means for unraveling some of the more interesting aspects that challenge our understanding of human performance.

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KINETIC ASSESSMENT OF MOTOR PERFORMANCE

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The major methods for assessment of human performance have been subjective ratings of the performance and tests based upon numerical scoring of repeated trials. Single or repeated observations of performance have been ranked subjectively according to a preprogrammed ideal image. Common rankings used are skilled, average, and unskilled or excellent, good, fair, and poor. Numerical scoring is commonly used in testing success in attaining a performance goal. For example, the performer scores eight free throws in 10 trials, accomplishes an agility run in 22 seconds, scores 32 points on a 10-trial badminton service test.

All these tests are indirect measurements of the actual performances and provide little information about the particulars of the performance. For example, the score of the agility run does not show whether the person had difficulty with all parts of the agility test or merely one part, such as movement to the left. Furthermore, it does not show whether body size influenced the score to a greater extent than did skill level. Indirect and relative or qualitative assessments do not provide the teacher and coach with enough information to aid them in improving the athlete's performance.

Kinetic assessment of performance, however, will provide such information. The skills of projecting one's body into space, such as in jumping activities, and projecting an object into space, such as in throwing activities, will be used to illustrate this type of assessment.

JUMPING

Most physical educators use the standard vertical jump test to determine the explosive power of elementary, junior high, and high school students, as well as college students. However, the height jumped may not be related to the height to which the center of gravity of the body is lifted. In testing a group of boys enrolled in a basketball summer camp, it was found that there was little predictive correlation between scores on the vertical jump and the height to which the center of gravity of the body was lifted (Adrian et al. 1975). One of the major problems associated with these children's vertical jump performances was the coordination of hand touch with the jump. Does the hand touch occur during the upward phase of the jump, at the peak, or on the descent? Thus, variation in jump-touch coordination may invalidate performance scores.

The method of assessment of body projection proposed in this paper is the analysis of force-time histories with respect to body weight. Performers jump from a force platform, and force-time patterns (as depicted in

Figure 1) are obtained. The top diagram represents a vertical jump of a skilled performer, whereas the bottom diagram is that of an average performer. The length of line Z allows the investigator to estimate the height of the jump from the air time. Each performer has a negative impulse caused by the preparation phase of the jump. The assessment of this negative impulse with the concommitant positive impulse allows the investigator to determine the effectiveness of the movement pattern. The slight dip in the positive impulse of the bottom diagram represents slight mistiming of the joint segments. The difference in slopes of the two positive impulses shows the greater extension velocity of the leg of the skilled performer. He was able to exert force over a shorter period of time and with a higher peak force.

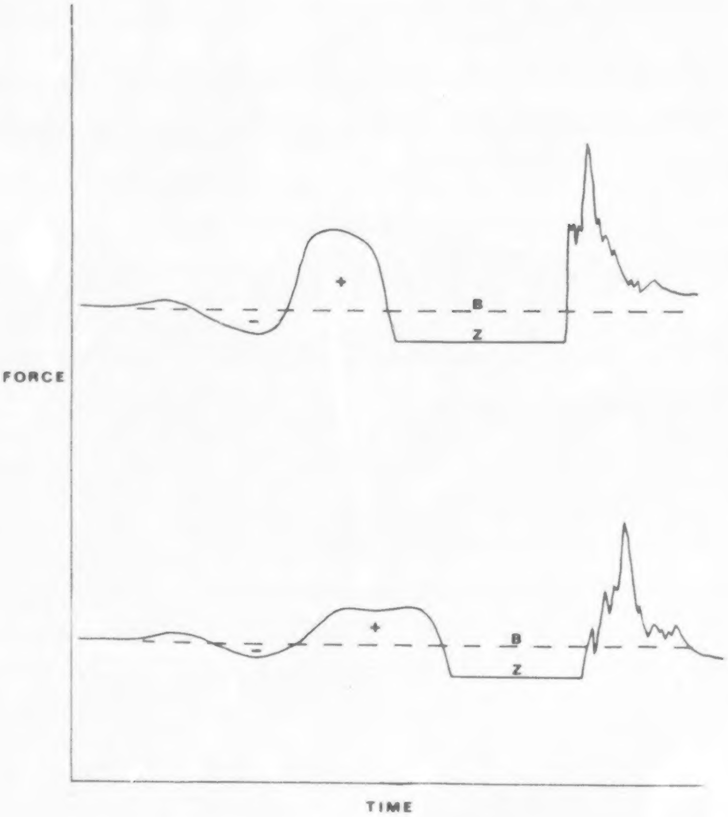

Figure 1. Force-time histories from two subjects performing the vertical jump. Top diagram is skilled performer; bottom diagram is average performer.

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The absolute values of the impulses cannot be the determining factor of the height jumped. The body weight must be considered. Since the impulse generated is equal to the change in momentum, the velocity of the jump is equal to the impulse divided by the mass of the jumper. The greater the velocity of the jump, the greater will be the height of the jump. Thus, if the two performers generate the same amount of impulse, but one weighs twice as much as the other, the one with twice the weight will jump half as high as the lighter jumper.

Teachers and coaches usually relate greater weight with greater muscle mass and expect better performances from their "bigger" students. However, sometimes greater weight is caused primarily by greater adipose tissue and not greater muscle tissue. Even if there were a greater amount of muscle tissue, muscle strength increases exponentially to the square while volume increases exponentially to the cube. This means that the heavier person remains at a disadvantage, all other factors being equal.

The assessment of force-time histories (impulse production) provides a means of determining the deficiencies within a performance. If there are no deficiencies, but the performance score is low, the logical problem rests with the state of the performer's body. Does he need to lose weight, become stronger, increase limb lengths, or obtain faster muscle fibers? Some of these factors can be changed easily, some with difficulty, and some cannot be changed.

The force platform method of assessment can be used in the investigation of standing and running long jumps, high jump, running, hurdling, vaulting, diving, skiing, fencing, and the like. Force platform data also may assist in the understanding of reaction forces with respect to injury analysis. Performance problems, such as the timing of the ski turn during the down unweighting phase, can be identified to determine causes of failures and successes. Combined with electrogoniometry, electromyography, and cinematography, kinetic analysis of movement can be limitless in aiding the teacher, coach, researcher, and athlete.

THROWING

If you threw a softball and a 6-year-old child threw a softball, who would be the better performer? Naturally your throw would be farther, but the distance of a throw does not necessarily indicate the skill level of a performer. The distance of a throw may be a function of spatial perception or body size, to name two factors.

A better method of assessing throwing skill would be to measure force production, work done, or the kinetic energy of the throw. These data can be obtained by measuring the speed of the projection of the ball. Dekan timers, photoelectric cells, high-speed photography, and velociometers have been used in assessing velocity of objects. Probably the most convenient assessment tool is the velociometer described by Roberts (1972). Using any of these tools, the speed of object projection can be related to length of limbs, segmental centers of mass, limb weights, muscle fiber types, and muscle mass in order to determine the effectiveness of an individual's performance.

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Another type of throwing analysis is of the kinetic energy produced during throwing. Theoretically, the kinetic energy produced should be the same for objects of varying masses, because increasing the mass of the object to be thrown decreases the velocity of the throw. However, this does not occur in practice. Miyashita* found that the person adjusts to the size and weight of the object by changing his pattern and using different muscles. Only through a relatively small range of weights will the patterns remain unchanged and the kinetic energies be identical.

A third type of throwing analysis partials out segmental phases of the throwing action. Miyashita* and Davis and Blanksby (1976) restrained subjects so that they performed each part of a throwing action in relation to each force production phase. Although not quite acurate with respect to actual use in the throw, segmental actions did identify possible weaknesses in the kinetic linkage system and problems in the sequential timing of the actions.

SUMMARY

In summary, this paper has stressed the necessity of assessing performance on some basis other than awarding of scores to subjective rankings. We need to know something about the performers: the height, weight, length and weight of limbs, lean body weight, cross-sectional area of muscle, and even muscle fiber types. We need to know enough about the person to be able to estimate abilities, capabilities, and deficiencies. Just as we know not everyone can be a Van Cliburn, not everyone can be a seven-foot high jumper. It is not realistic to expect all people to jump so high or throw so far. Possibly we might say that all those persons so tall or so heavy or with such-and-such a lean body weight should perform at such-and-such a level. Even this type of assessment has limitations, but it allows for a more scientific estimate of performance. Kinetic analysis provides guidance to the teacher and coach in the individualization of instruction, the setting of realistic performance goals, and identification of causes of deficient or unsatisfactory performances. Through an understanding of, and research into, the kinetics of motor performance, we will be able to facilitate the improvement of performances of girls and women in sport.

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